DIFFERENCES BETWEEN THE SEXES
IN SENSORY SENSITIVITY AND PERFORMANCE
FOR THE VISUAL AND AUDITORY MODALITIES

by

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ABSTRACT

50 young adult males and 50 females undertook a series of psychophysical experiments in the auditory and visual modalities, testing (i) sensory threshold, (ii) the subjective response to intensity, and (iii) discriminatory ability (the Phase 1 experiments). Significant differences between the sexes in performance in the auditory modality were found in absolute threshold for some frequencies with females being more sensitive in each instance. In their subjective response to intensity in the auditory modality, females consistently set levels 8 - 9 dB lower than those set by males at all frequencies. In all instances the difference was statistically significant. No significant differences between the sexes were obtained in their ability to discriminate pitch. In the visual modality significant differences between the sexes are not apparent for dark adaptation (used as a test of threshold) or the subjective reaction to intensity (glare). Analysis of the visual acuity scores (discriminatory ability) shows a sex difference in favour of the males ($p > 0.01$). Extensive correlational analyses are employed to examine within-mode and inter-modality relationships. The lack of consistent significant and high relationships obtained indicate that sensory sensitivity is not a consistent property of the nervous system, and presents some problems for current theories of personality. The effects of the menstrual cycle on female performance in the auditory and visual modality tasks are also considered, and the data indicates that hormonal influences are implicated.

Having established that some differences between the sexes do exist in the performance of visual and auditory tasks at the sensory or basic perceptual levels, the second phase experiments (administering the Bennett Differential Aptitude Tests) were commenced. The rationale and methodology for these experiments is described. Significant differences between the male and female groups in this study were not apparent in any of the Verbal/Language Usage tests, but significant differences in favour of the males were obtained for Space Relations ($p > 0.05$) and Mechanical Reasoning ($p > 0.02$).

Correlational analyses between the auditory and visual parameters and the cognitive abilities tested on the Bennett DAT showed high significant relationships ($p > 0.01$) between auditory intensity tolerance and all the Verbal/Language Usage tests, and a significant relationship for the total sample ($p > 0.05$) between visual acuity and the Space Relations test.

The implications of the data obtained in this study for existing theories of sex differences are discussed.

CONTENTS

TABLES

FIGURES

ILLUSTRATIONS

ACKNOWLEDGEMENTS

- x -

CHAPTER 1

STATEMENT OF THE PROBLEM

INTRODUCTION

For many centuries, in our culture and apparently in most others, the view persisted that women were biologically inferior to men. The physical weakness of the female was taken as an indication of overall weakness and inferiority when compared to the male. It was believed that in reproduction the male was the active form-giving agent, whilst the female provided only soil and nourishment, and this belief continued to affect attitudes long after research in heredity discredited it completely as a description of facts. Although numerous books were written on the differences between men and women (usually to the detriment of the latter) there was little, if any, research of a scientific nature until the present century (see Woolley, 1910; 1914).

Two conclusions have dominated the approach to research on the subject of sex differences since the beginning of this century, namely the smallness of psychological differences between the sexes on measurements of ability, and the possibility of accounting for those differences that have been found in terms of sociological rather than biological causes. Furthermore, the study of differences between the sexes, in common with other group comparisons, presents a number of methodological difficulties. The wide range of individual differences found within each sex, with the consequent overlapping between their distributions is a major problem - as Samuel Johnson is reputed to have said, when asked which is more intelligent, man or woman, "which man, which woman?" Since in any psychological trait men differ widely from one another, and women similarly vary among themselves, any relationship found between group averages will not necessarily hold for individual cases. This factor (taken in conjunction with the small samples commonly used), as much as any other, may well have obscured the existence of sex differences per se in behavioural research. The situation is further confused by the belief that different personality types exist within the two sexes, and that certain behavioural patterns conform to specific personality traits.

Thus, whilst it is readily accepted that differences exist between the sexes in certain physiological parameters, the existence

of psychological differences between the sexes has aroused much
greater controversy.   Nevertheless psychological and behavioural
differences between the sexes have been observed and reported by
researchers at all stages of growth and development.   In one
comprehensive review of such sex differences, Garai and Scheinfeld
(1968) indicate a number of behavioural and cognitive abilities
in which males and females are reported to differ.   For example,
females appear to excel in certain linguistic skills, whereas
males have more aptitude in tasks requiring spatial-mechanical
abilities.   They further indicate that at an early stage in life
the evidence suggests that males respond more and have a greater
sensitivity to stimuli presented in the visual modality, whilst
females show a similar preference for auditory stimuli.   Garai
and Scheinfeld state:

> "One might postulate a 'visual stimulus hunger' of the
> boys and an 'auditory stimulus hunger' of the girls"

They imply that if the two sexes do begin life with different
perceptual biases, this will almost certainly affect development,
and would in part explain certain differences in aptitudes or
interests that are detected later in life -

> "a difference in sense modality between the sexes...
> if corroborated... would provide an explanation for
> the apparent tendency of girls to develop superior
> verbal skills, as well as for that of boys to excel
> in spatial perception'.

This suggestion has two important implications.   The first
relates to the study of perception, and in particular the importance
of the sensitivity of sensory receptor systems as part of the
perceptual process, influencing cognitive and behavioural development.
The second concerns the nature of differences between the sexes in
cognitive and behavioural abilities, since it would seem to imply that
such differences are primarily biological in origin.   This would
support the bio-determinist position, in which not only are basic
sensory differences assumed to be innate, but cognitive abilities are
similarly purported to be pre-ordained, with certain brain structures
actually pre-determining the ultimate intellectual aptitude (Hutt, 1972;
Buffery and Gray 1972).

These two issues form the basis of this thesis, the central purpose of which is to investigate, using psychophysical methods of investigation, whether or not significant differences exist between the sexes in visual and auditory sensitivity, in a group of young adults. The information thus obtained, together with evidence from a review of the literature on sex differences in a number of developmental, behavioural and cognitive parameters will then be used to discuss the dichotomy which has developed between cultural and biological hypotheses as explanations of the differences between the sexes in cognitive and behavioural abilities. In particular, consideration will be given to the possible relationship between sensory sensitivity in the auditory and visual modalities and certain differences between the sexes in aptitudes and interests that are detected later in life. Exploration of the existence of such a relationship between sensory sensitivity and the perceptual process is the second major issue with which this investigation is concerned. This chapter provides an introduction to these issues.

BIOLOGICAL AND SOCIO-CULTURAL ARGUMENTS: A DICHOTOMY

Most of the research into psychological and behavioural differences between the sexes may be divided into two divergent, often antithetical views about their nature and their source. The first approach, which includes recent formulations of analytic theory and the work of the social learning theorists, proposes that sex differences are due primarily to social environmental conditions which shape and influence male and female behaviour. The second approach, based initially on a Freudian model of sex role development is characterised by its emphasis on anatomical and biological differences as the primary basis for the existence of these differences. The logic of these explanations is often questionable, but their greater weakness is in the adoption of an extremist position, placing the entire cause on either cultural or biological factors, on the basis of relatively little supportive evidence. Studies of individual differences, however, have consistently shown that development always involves an interaction of both genetic and environmental factors. Man is essentially a biological as well as a social being, and his behaviour is the product of biological evolution as well as of cultural differences. Failure to recognise the biological basis of differences in behaviour and perception, as well as the social and cultural determinants, will restrict our eventual understanding and possible control of the major sources of

diversity in human capacities and potentialities.

In essence, the most extreme form of cultural or environmental theories state that differences in development are determined by something that the parents or other socialising influences do, or do not do, to the child. The findings for sex differences in behaviour are explained in terms of differential learning, and the focus is on society as the prime determinant of masculinity and femininity. Once the child has been reinforced for sex-appropriate behaviour, it becomes increasingly difficult for him or her to change to the other one without considerable conflict and tension. All the details of the general sex differences in behaviour are thought to arise from these culturally imposed restraints. For example, Barry et al (1952) purported to survey sex differences in socialisation in 110 cultures. The response measures consisted of ratings of the degree of pressure parents applied towards the establishment of behaviours appropriate to such variables as obedience, nurturance, responsibility, achievement and self-reliance. They concluded that differentiation of the sexes was unimportant in infancy, but in childhood females were encouraged to develop a greater degree of obedience, nurturance and responsibility, whilst achievement and self-reliance were considered more important for males. Since they found that societies varied in the emphasis they placed on particular variables, a cultural rather than a directly biological argument for sex differences was supported.

Although most cultural theorists accept some modification of this extreme position, until very recently they have tended to dismiss the acceptability of other explanations for the existence of behavioural and psychological differences between the sexes. Maccoby (1967) and Maccoby and Jacklin (1974) present several hypotheses of this type. However, in order to show that there are behavioural differences which are scarcely mediated by experience, Thomas et al. (1969), using longitudinal methodology, were able to demonstrate that each child in fact has persistent, innate, temperamental traits which continue into adult life. Similarly, Bardwick (1971) has listed a range of responses (for example, gross motor activity and pain sensitivity) on which newborn males and females have been reported to differ significantly, thus calling into question the belief that all behaviour could be attributed to differential reinforcement by the parent. Both studies suggest that the

interaction of innate temperament and parental handling is crucial
to the healthy psychological development of the child.

There is thus some evidence to suggest that even very young
infants have different sensitivities and biases, and research that
will be reviewed in the next chapter indicates that certain of these
show marked variations between the sexes. These differences not
only give rise to different types of behaviour in infant and child,
but may also modify the behaviour of parents towards infants: for
example, Moss (1967) observed that the male infant's demanding
cries led to them being picked up more frequently than females,
who are, according to Lewis (1972), more easily appeased by distal
stimulation. Thus reinforcement is a two-way interaction between
infant and parent. A mother is more likely to direct her speech
to the infant if it responds by smiling and babbling, than if the
infant responds negatively. This interaction poses problems in
determining the precise antecedents of behaviour.

Opponents of a purely environmental theory have frequently
resorted to citing instances in which differential reinforcement
fails to provide a satisfactory explanation. For example, the
reasons put forward by the cultural theorists to explain females'
superiority in linguistic skills and male superiority in visual-
spatial skills (Tyler, 1965) presume that they arise as a result of
different emphases on these aptitudes in infancy and early childhood.
If these differences cannot be demonstrated, it is suggested that
some subtle differences in the behaviour of the mother is influencing
the sexes selectively (the early weeks of life are considered
critical by many cultural theorists). For this reason a section
on the early manifestations of sex differences has been included
in the next chapter, and this section will also include a consideration
of parental reinforcement of these behaviours.

The fact that a number of sex differences are consistent
throughout the developmental stages, and may be observed in very young
infants, together with the evidence presented by hormonal and other
studies make acceptance of a purely cultural/environmental explanation
of these sex differences very difficult. Moreover, this type of
theory, whilst it may account for many of the cognitive and motivational
differences between the sexes, leaves unanswered the questions of

1. whether possessing a 'male' or 'female' nervous system facilitates the learning of the appropriate sex role, and 2. whether sex differences originate as the indirect consequence of human evolution.

Bio-determinist arguments seek to replace culturally based theories with those emphasising determinants more firmly rooted in physiological differences between the sexes. Such explanations have their roots in man's evolutionary past, when the traditional sex roles evolved, it is suggested, from the division of labour in hunter-gatherer societies (Pilbeam 1972) together with the development of differences between men and women in visual-spatial and verbal skills (Leakey and Lewin 1977). This last argument suggests that the separate abilities have arisen through a process of natural selection resulting from the division of labour: spatial perceptual traits being advantageous to the male hunter, while the females, who were less mobile, particularly during periods of pregnancy and nurturance of the young, acted as gatherers of fruits and berries and spent more time in a sociable camp atmosphere, engaged in the full-time education of children, and therefore had a greater need of verbal skills.

Biological explanations take three main forms: developmental lag theories, cerebral dominance theories and hormonal theories. The first argue that although both sexes go through virtually identical developmental stages, the advanced physical maturity of the female means that she always arrives at a cognitive stage earlier than the male (see Garai and Scheinfeld, 1968). This type of theory was devised originally to explain the female's earlier display of language ability, and has since been applied to other forms of cognitive ability. Evidence demonstrating a continued superiority by females beyond the developmental period, or male superiority in certain skills in the early stages of development would argue against the acceptability of this type of theory (see Chapter 2).

Cerebral dominance theories to some extent incorporate developmental lag theory, but are extended to propose that there are more inherent and enduring cognitive differences between the sexes. Developed primarily to explain the existence of differences in verbal and visual-spatial abilities, cerebral dominance theories propose that sex differences in these abilities arise because the cerebral hemispheres of males and females have different structural capacities (Buffery and Gray, 1972). It is also suggested that they contribute to a more general treatment

of sex differences in the emotional and cognitive behaviour of
mammals. In support of this type of theory Buffery and Gray draw
upon evidence from animal and human studies in which differences
in spatial abilities have been observed, and linking superior visual-
spatial abilities to a recessive gene carried on the X chromosome
(Stafford, 1961). It has been estimated that this recessive
allele is possessed by approximately 50 per cent of the male
population, compared to only approximately 25 per cent of females
(Bock: cited by Garron, 1970). Evidence is then presented showing
sex differences in linguistic abilities from human studies only
(for obvious reasons). Having established the existence of such
differences and tracing to some extent their ontogenetic development,
evidence is then presented from experimental and clinical
investigations of asymmetries in the function and structure of the
left and right cerebral hemispheres of the human brain, and the
existence of sex differences in such asymmetries (brought about
under hormonal influences during the early years of life).

On the basis of such evidence Buffery and Gray propose that the
human brain has an innate, species-specific and lateralised (usually
left-sided) neural mechanism which is specialised for the extraction
of certain linguistic features in speech perception. Other neural
structures, in the proximity of the innate neural mechanism for
speech perception, may develop verbal functions and thereby contribute
to the establishment of a cerebral hemisphere dominant for language,
and to those asymmetries of non-verbal (especially spatial) function
also characteristic of the human brain. The innate neural mechanism
for speech perception is more developed in the female than male brain
of the same age, and this has two major consequences, the first
direct and the second indirect. The direct consequences is the
lateralisation of a usually left-sided cerebral dominance for language
function is accelerated in the female brain and such functional
topography facilitates the development of linguistic skill in women.
The indirect consequence of a more bi-lateral (though usually
predominantly right-sided) cerebral representation for non-verbal
function is established in the male than in the female brain and
such functional topography facilitates the development of spatial
skill (Buffery and Gray, 1972). As an explanation of sex differences
in verbal and visual-spatial abilities, such theories appear both
plausible and adequate. In their suggestion, however, that cognitive

structures are not only pre-wired, but of fixed capacity, they fail to allow for the plasticity of neural tissue, and no consideration is given to the sensory mechanisms which may serve these abilities (to be discussed later).

The importance of adult levels of sex hormones, rather than developmental sex differences, as determinants of performance in perceptual motor tasks has been stressed by Broverman et al. (1968) and Andrew (1972). It is proposed that androgens affect central neural mechanisms in one way, whilst female hormones (particularly oestrogens) have a different effect. The basic premise arising · from their investigation) proposed by Broverman et al. is that women perform better than men on simple, overlearned perceptual-motor tasks (for example, clerical skills, field-dependence tests, verbal fluency), but that men surpass women on the more complex 'perceptual restructuring' tasks which require inhibition of the immediate response to obvious stimulus attributes (for example tests of field-independence). These differences were related by Broverman et al. to different effects on the brain of androgens and oestrogens, suggesting that the latter facilitate 'activation' by stimulating adrenergic mechanisms, whereas androgens are weaker in this respect and facilitate 'inhibition'. This theory has been criticised on two counts. Singer and Montgomery (1969) have questioned its interpretation of the pharmacological evidence, whilst Parlee (1972) has pointed out that their evidence was selective and omitted those tasks which did not fit their basic premise on the nature of sex differences.

Andrew (1972) derived his hypothesis from work on food-searching strategies in young male chicks injected with testosterone, in which he found that testosterone leads to increased "persistence". Thus the animal attends for longer, either to a spatial locality or to a particular type of stimulus, and is less readily distracted by irrelevant stimuli (Andrew and Rogers, 1972; Andrew, 1972; Archer, 1974). Andrew interpreted work on human subjects showing that high-androgen men perform better than low-androgen men in relatively simple tasks involving attention to a restricted set of particular stimuli (Broverman et al, 1964; Klaiber et al, 1967; 1971) as being essentially similar to the effects of testosterone on visual search in chicks. He has also suggested that a lack of androgen is associated with better performance on tests involving frequent switches of attention

(for example the clerical abilities outlined by Garai and Scheinfeld, 1968).

Diamond et al. (1972) maintain that both male and female hormone levels may effect performance in the visual and auditory modalities, and that the cyclical changes in hormone levels accompanying the menstrual cycle in females may play a part. The proposal by Diamond et al. that differences in sensitivity in a number of modalities is related to sexual behaviour in the female provides a link with earlier hormonal studies (primarily with lower-order mammals). In these it was suggested that androgens were associated with increased sexual behaviour and aggression (see Rogers, 1976 for review). Female hormones, on the other hand, were associated with maternal behaviour (in which it is believed that oestrogens, progestogens and prolactin are implicated), a cyclical control of sexual behaviour and less aggressive behaviour, except in some species (see Messent, 1976 for review).

The suggestion that hormonal factors are important determinants of behaviour provides an easy and apparently credible explanation of sex differences. There are, however, a number of problems which militate against acceptance of hormonal influences being the only or even the prime determinants of behaviour, particularly since much of the evidence coming from hormonal studies may be criticised on methodological grounds. Where investigations have used lower-order mammals, one cannot always infer that the reactions obtained necessarily parallel the reactions of the human or refer to clearly compatible characteristics, even where there seems, at first sight, a close correspondence between animal and human findings. For example, the findings on sex differences in aggression (Gray, 1971; Archer, 1976) refer in animals to measures such as the latency of initial attack, threat displays, and the duration and outcome of fighting, whereas many of the human studies use different measurements of aggression-verbal aggression, teacher's ratings of impulsivity and assertiveness, laboratory experiments simulating administration of electric shocks, questionnaire and personality studies (see Maccoby and Jacklin, 1974 for review). Similarly Broverman et al. (1968) measured "rapid repetitive responding" in humans using the speed of colour naming, clerical aptitude tests, manual dexterity, speech and reading ability, speed of eyeblink conditioning and sensory thresholds. In the rat the same characteristic

was measured by tests of wheel running activity, ambulation in an open field, and speed of avoidance conditioning. Therefore theories based on animal studies are, perhaps, best viewed as useful in stimulating research on possible biological factors involved in human sex differences, rather than as providing any complete or correct answers per se.

In hormonal investigations of human subjects, anomalies arise following either abnormal intervention with biological functioning, or an assessment of individuals with abnormal chromosomal development. Investigations of individuals with abnormal sexual development and hermaphroditism have shown that many of these individuals adjust adequately to their sex of assignment or choice irrespective of their genetic or hormonal sex (Money et al, 1955a & b; Money and Erhardt, 1972;).

Paradoxical results have, furthermore, been obtained in hormonal studies, in both humans and animals. For example, Klaiber et al. (1971) report better performance in the Stroop Test by more androgenised males - yet Peretti (1969) concluded that females normally excel in this type of test. Harris (1970) found that the female newborn rat becomes masculinised after small doses of oestradise, whilst in studies of the menstrual cycle Diamond et al. (1972) and Baker and Weiler (1977) found that females taking an oral contraceptive tended to perform more like the male subjects than normally ovulating females in tests of sensory threshold. Hormonal factors also fail to adequately explain the great number of differences observed between the sexes in early childhood. For example, Lunde and Hamburg (1972) maintain that the onset of sex differences in spatial ability seems to occur between one to four years before androgen levels have risen appreciably.

Rogers (1976) urges caution in the interpretation of studies where hormones are administered, on the grounds that an administered hormone may be transformed into another steroid in the body, and that where high doses are given, they may be acting non-specifically. Furthermore, she points out, even in animal experiments learning factors have been shown to be important, sometimes even to the extent of over-riding hormonal effects. In animals, environmental factors such as high population density, continual defeat, or prolonged subordination can affect the pituitary-adrenal system (Bronson and Eleftheriou, 1965), which has some relevance for an interactionist viewpoint, suggesting that,

whilst hormonal levels may affect behaviour, these hormonal levels may in turn be affected by socio-cultural influences, a suggestion which is further supported by McClintock (1971), in a study of the development of synchrony in the menstrual cycle of female students over a six month period. McClintock assessed the developing similarity in dates of onset in pairs of room-mates and of close friends, and showed an effect in comparison with random pairings. These results rules out common diet and daily routine as causal factors and further analyses based upon division of the total sample into larger groups based upon time spent together and living units determined geographically, found the synchronisation effect only in friendship groups. Whilst McClintock could give no precise reason for her findings, an interaction between biological and environmental factors would seem to be implicated.

The bio-determinist view is succinctly put by Hutt (1972). In her review of sex differences she concludes that from the very early weeks of uterine life, males and females develop in characteristically different ways, under the influence of the respective genetic complements, which confer special properties on the course of development, and the gonadal hormones, particularly testosterone, which have important formative and organisational functions. Even intro-uterine factors affect male and female fetuses differently. Differences in structure, metabolism, physiological and psychological functions characterise the development of the two sexes from the moment Of birth onwards, and many of these differences are common not only to other societies, but also other primates, making a purely environmental interpretation of sex differences unacceptable.

Further, Hutt maintains that the characteristic patterns of behaviour and styles of development of males and females are particularly well suited to the roles that they fulfill, and have differentiated as part of the evolutionary process. This does not discount the role of experience or learning, but implies that experience acts on structure and machinery which is already biased to function in one particular direction more than another.

Studies of sensory capacity and sensitivity like the one undertaken in this investigation may provide evidence which appears to strengthen the bio-determinist argument. Differences in sensory

sensitivity are difficult to explain culturally - especially if these differences are found to be not only consistent between sexes at all ages, but endure into adulthood. In adopting such an approach, however, and treating innate and environmental sources of variation as if they were additive processes, writers such as Hutt propose a simple theoretical model which implies that genetic factors can impose readily definable limits on behavioural characteristics, and that culture can only accentuate or attenuate sex differences already extant in the genome. It may thus be seen as an attempt to set right a balance of biological and experiential factors which had in the past swung too heavily to the nurture side. A third alternative is possible as an explanation of sex differences, however, involving an interaction of the two sets of factors. In this approach consideration is given to the question of how the genetic material interacts with the environment, rather than seeking to assign behavioural traits to either nature or nurture. In an interactive model involving repeated action and reaction between the organism and its environment, nature and nurture are seen as abstractions from a process that involves both components at the outset, and not as two separate variables bearing an additive relationship to one another (see Archer and Lloyd, 1975). This approach is central to the arguments developed in this investigation.

AN INTERACTIONIST VIEWPOINT.

Lehrman (1970) has pointed out that much of the confusion related to the nature/nurture argument has arisen from considering behavioural characteristics both at the level of the species as a whole and at the individual level. At the species level, the term innate may be useful to designate that a particular aspect of behaviour is subject to alteration by genetic selection, but does not imply anything about how readily the underlying developmental processes for such behaviour are subject to modification by experience at the individual level. Thus the existence of a genetic influence on a sexually-dimorphic behavioural characteristic implies that it is amenable to alteration by natural selection, but tells us nothing about the extent to which it may be modified by different environmental factors.

In considering the development of sex differences, one should ask how the biological material interacts with the environment, rather than seeking to assign behavioural traits to either nature or

nurture. One might further ask how a biologically-influenced trait is expressed in the range of environmental conditions in which it may develop. Experiments with rodents have shown that hormonally-influenced sex differences are environmentally labile (Swanson, 1969; Gray et al. 1969). In humans, cross-cultural studies of performance on the Witkin rod and frame test have shown that the typical sex differences (Witkin et al. 1962) are not detected in some cultures, for example Eskimos and Zambians (Barry, 1966; MacArthur, 1967; Siann, 1972). Thus, if hormonal sex differences influence these attentional processes, it is possible that these influences interact with the particular individual's educational and cultural background.

Theories of sex differences should, therefore, emphasise the interaction between environmental factors (education, parental attitudes, wider cultural norms) and biological ones (anatomical, developmental and neuro-endocrinological differences) rather than being stated in terms of a learnt or innate dichotomy. Interactionist theories are bound to be complex, and will involve the incorporation of a number of the theories already discussed. Concentration upon any one dimension is unlikely to provide any real understanding of the origin of sex differences in cognitive skills. The combination of variables, together with a time perspective is necessary to explain adequately any form of complex development. In the next chapter a speculative interactionist explanation relating sex differences in auditory and visual sensory sensitivity to those apparent in the cognitive verbal and visual-spatial abilities is presented, in which developmental lag, hemisphere dominance, anatomical and hormonal theories are incorporated, interacting with cultural factors.

This explanation is related to Garai and Scheinfeld's (1968) proposition that the sexes begin life with different modality preferences, and therefore with different perceptual biases, which influence the differential development of verbal and visual/spatial skills. As stated earlier, this has important implications for the study of perception, particularly the way in which the sensitivity of a receptor might act as part of the perceptual process in influencing cognitive and behavioural development. It is to this problem that some attention must now be given.

SENSATION, PERCEPTION AND ATTENTION.

Perception is concerned with the way in which the observer

relates to his environment - the way in which information is gathered
and interpreted by the observer. This relationship is the result of a
continuing process of learning, judging, interpreting and reacting
to the environment which begins at birth and continues throughout the
lifespan of the individual.

Most psychologists today are careful to distinguish between
'sensation' and 'perception'. Stimuli coming from various external
objects and happenings affect one or other of the sensory areas of the
brain and cause us to experience a 'sensation' (the response of a sensory
receptor to a stimulus), but our interpretation of the environment - or
'perception' is much more than sensations received; it is sensation
reinforced by ideas, images and past experiences. Perception is thus
seen largely as a cognitive process involving the encoding of the
stimuli received as sensations (Garner, 1962).

Historically, the concept of sensation developed from the
structuralist's mid-nineteenth-century notion of specific nerve energies.
They held that for every sensation a specific receptor and neuron
existed which fired to indicate the presence of a physical stimulus.
However, neurophysiology has shown that this is not the case, and
rather than specific nerves, the important variables seem to be spatial
and temporal firing (pattern discharge), the portion of the cortex to
which the receptor reports and the other brain centres activated in
processing the input.

By the beginning of this century disillusionment with
structuralist theories gave rise to attacks being made on the view that
the same stimulus always gives rise to the same sensations, and by the
end of the second decade the emphasis was on the importance of whole
meanings, independent of sensation, to the study of perception. The
Gestalt psychologists, largely as a reaction against those researchers
who accepted only measurable behaviour as experimental evidence and the
psychophysicists who seemed preoccupied with physiological concepts,
developed experimental techniques in which they were able to demonstrate
that the whole is greater than the sum of its parts, and their theory
went on to stress the immediacy and validity of perceptual experience.
This purely behavioural approach has relegated to a minor position,
the contribution of sensory capacity to the evolution of perception in
perceptual studies in the present century.

The suggestion of von Fiandt (1966) that the term sensation
can be used for denoting the functional interaction process between
periphery and organs and the corresponding loci in the brain implies
that sensory psychology is therefore a matter of the physiology of
neural transmission in the senses, while perception can be considered
the response of the organism that utilises the message. However,
not all perceptual psychologists agree with such a description of
perception and sensation. Dember (1960), for example, asserts that
both are part of the same continuous process and rejects their separation,
while Gibson (1966) prefers to consider incoming sensory information
as only a minor part of perception. He sees perception as more than
the mere encoding of sensory messages: rather, it is an active process
of extracting information from the environment - a process of
exploring, seeking out, and responding in continual interaction between
organism.

This last view of perception, in common with many contemporary
viewpoints, emphasises the importance of such cognitive elements
of perception as memory, selective attention and higher order cognitive
systems, and is supported by Murch (1973), who proposes a model of the
perceptual process in which each individual observer is seen as an active
perceiver engaged in extracting information from his environment, with
the kinds of information extracted and the resulting analysis and
redirection of search developing as a function of the observer's
interactions with the environment. The programmes of motor activity
and the properties of effective stimuli required for a direction of
attention depend on these past developments, so that each person is
an individual perceiver who interacts with his own subjective world.
This approach, whilst it provides an essentially valid description of
the perceptual process, and emphasises the importance of interactions
between biological and cultural factors, places little emphasis on the
contribution of sensory capacity to the evolution of perception.

From among the deluge of potential stimuli, the human organism
can attend only to very few at a given moment. Limited as to the
amount of information he can process, the observer is forced to perceive
or respond to less than the total array. This process is referred to
as attention, one of the most influential descriptions of which was
developed by Broadbent (1958). In his model he assumed that when
several stimuli impinge on the senses, each evokes an initial response,
but experimental observations indicate that the observer's capacity for

processing stimuli from the environment is limited. At some point
in the perceptual process, then, some stimuli must be selected for
further processing and some disregarded. Broadbent proposed the
existence of a selective filter followed by a bottleneck (limited
capacity channel) which selects some of the incoming impulses for
processing in the brain. The central filtering process involves some
type of short-term memory system which selects and maintains information
for further processing. Basically, the filter model is taken from
communications theory, and provides an explanation of how selective
attention is managed. Thus attention is seen as the mechanism
enabling organisms to respond selectively to important features of
the environment and ignore those which are of little or no importance
(Egeth, 1967). As such, attention is seen as fundamental to the
preceptual process, but in this description the importance of the
efficiency of the sensory channels in terms of their discriminative
capacity to distinguish between input signals is neglected (see Gibson
and Gibson, 1955). The importance of sensory channel discriminative
efficiency has been emphasised by Lindsay (1970), who demonstrated
that when signals were made difficult to discriminate, the amount of
information processed was drastically reduced, while Garner (1962)
noted that processing efficiency for multi-dimensional input is always
less than the sum of information transmitted by single channels
separately. In reviewing the evidence on animal discrimination
learning, Honig (1970) also underlines the importance of the
discriminative capacity of the sensory channels, concluding that
animals select certain aspects of a stimulus in preference to others,
and that selectivity operates because certain stimuli are more easy
to discriminate on some dimensions. Thus, ease of discrimination
would appear to affect both the amount of information processed and
the modality or channel which reviews attetnion. Attention is likely
to be more easily directed to the most efficient channel, and the modality
which contains the greater number of signals which are easy to
discriminate, will tend to dominate other modalities.

This issue is also pursued by Pribram, (1971) who argues that
attention will be directed to the sensory channels with the greatest
'competence' - those neural pathways with the greatest efficiency.
Efficiency leads to an increase of the flow if information along these
pathways, and in turn to an increase in the amount of attention paid
to this input. Increasing attention, in turn, produces more efficient

transmission in an apparently circular process. Competence predicts attentiveness, and channels become competent either because of intrinsic unlearned properties or because of training. This implies that attending to incompetent channels will require greater effort, and this in turn will reduce the amount of information transmitted because the interference or noise levels on incompetent channels will be higher. Innate potential directs experience because it is easier to acquire competence in learning about the environment using innately efficient mechanisms, but this does not mean that inefficient mechanisms cannot be made more efficient. This approach thus allows for genetic potential and for modification through interaction with maturational and cultural experience, and we shall be returning to this discussion in the next, and ensuing chapters.

HYPOTHESES

Earlier in this chapter mention was made of the suggestion, first made by Garai and Scheinfeld (1968) that the two sexes begin life with different perceptual biases in the visual and auditory modalities. They suggest that this affects development and this, in part, would explain certain cognitive differences in visuo-spatial and verbal skills. A consideration of the arguments presented in this chapter lends support to this position and gives rise to the following hypotheses:

1. Females have a greater sensitivity to auditory stimuli than males.

2. Males have a greater sensitivity to visual stimuli than females.

3. Superior sensitivity to auditory stimuli is related to the superior development of verbal skills.

4. Superior sensitivity to visual stimuli is related to the superior development of spatial-mechanical skills.

5a. There is a difference in auditory and visual sensory sensitivity between the sexes which is biological in origin.

5b.   This difference leads to a sense modality preference and is
      related to differences in the development of certain cognitive
      abilities.

      These hypotheses will be tested in this thesis, after a
review of relevant research.

CHAPTER 2

REVIEW OF THE LITERATURE - SEX DIFFERENCES

INTRODUCTION

In a study of this type it would be inappropriate to undertake a full and comprehensive review of all the current literature available concerning the differences between men and women in all the behavioural and psychological parameters. It is necessary to organise the review within a framework relevant to this particular thesis, which presents an investigation into the visual and auditory sensory processes in young adult men and women. It is hoped that the information obtained, together with the data already available from the studies of other researchers, may be used firstly in determining whether any innate differences can be demonstrated between the sexes, and the possible effects of an interaction between innate and socio-cultural factors on these differences during development. Secondly, it may be used in speculating the mechanisms by which certain sensitivities might bias attention and affect the subsequent development of perceptual and cognitive abilities and behaviour.

This chapter, then, is divided into five main sections in order to discuss the two problems. These may be categorised as follows:-

Section 1. A review of the information concerning the biological differences between the sexes, including the development of the embryo and the physical growth and maturation of the two sexes. This section shows the existence of very basic differences between the sexes which are certainly biogenetically determined and which provide a basis for other likely sex differences.

Section 2. A discussion of the evidence of early manifestations of sex differences in the neonate and very young infant, particularly in relation to their responses to different types of stimuli (visual and auditory).

Section 3. This section provides the foundation for the experimental work in this study, in which the evidence for differences in sensory sensitivity is presented. Such differences are difficult to explain on a purely cultural basis, since the subject has little or no control over basic sensitivities.

Section 4.   A discussion of special abilities in males and females, in which some consideration is given to the suggestion that these, too, have a biological derivation to some extent.

Section 5.   The sex differences outlined in the previous sections are discussed in relation to current theories, and in particular to an explanation related to the suggestion of Garai and Scheinfeld (1968) that sensory sensitivities influence the development of perceptual and cognitive processes.

1.   BIOLOGICAL DIFFERENCES

A.   Sex differences in the Development of the Embryo.

It has been pointed out (Garai and Scheinfeld, 1968) that males and females exhibit radically different patterns of development from the moment of conception.   Hunt (1966) has shown that the Barr bodies are evident in the female cells on the 16th day and the bipotential gonad begins differentiating after the seventh week, the medulla developing in the male and the cortex in the female.   This differentiation is determined by the XY sex chromosomal complement in the male and the XX in the female.   The primary function of the Y chromosome is apparently to organise masculine development (Gates and Bhaduri, 1961) - in the absence of the Y chromosome, it is apparently the natural propensity of mammals to develop according to a female pattern.

Once the fetal testis is formed it produces an androgen thought to resemble testosterone.   This androgen organises the Wolffian ducts of the embryo into the male genital tract and organs and simultaneously induces regression of the Mullerian ducts.   In the absence of androgens only female differentiation can take place even in a genetic male.   Hutt (1972) cites evidence from a number of studies which amply demonstrates the potent and critical role of the male gonadal hormone.

Excessive androgen production in the human may arise from one of two causes.   In the first instance, an inborn error of metabolism produces a surfeit of androgens (but not testosterone) from the adrenal glands.   Such an excess has a negligible effect on the male fetus, but in the female male genitalia develop (Federman, 1967), and many

behavioural characteristics develop, according to Money and Erhardt (1968), a 'male flavour'. The second instance arises when the drug Progestin is administered to pregnant mothers who are liable to miscarry. The drug ensures implantation of the embryo, but its androgenic properties cause masculinisation of the female fetus. Money and Erhardt describe four such androgenised females, two of whom chose to be men, and two women. They further show how genetic females exposed to androgens in prenatal life differ in behaviour, attitudes and interests from females who have not been exposed to the influence of any gonadal hormone during this critical period.

Similarly evidence exists for both animals and humans to show that when genetic males are deprived of their gonadal hormone they are unable to differentiate as males (Hutt, 1972). For example, in humans an autosomal recessive gene causes the testes to be both structurally and functionally abnormal, being located in most cases either in the abdomen or in an inguinal hernia. In the absence of androgens or androgenic action the genital tract and external genitalia differentiate in the female pattern, and most secondary female sex characteristics develop (Valentine, 1966; Federman, 1967).

However, it is not merely the reproductive systems that differentiate into a male and female type, but the central nervous system also (Harris and Levine, 1965). There is thus a differentiation of the brain into a male or female type since the regulation of gonadal hormones is cyclic in the female and acyclic in the male, and it is believed that the regulatory centre lies in the hypothalamus. Harris (1964) points out that the gonadal hormones exert a dual action on the central nervous system; during fetal life they act in a inductive manner to organise it into a male or female type of brain, and during adult life they act in an activational way in the neural control of gonadotrophic hormone (GTH) secretion as well as in the expression of sexual behaviour.

In the human fetus male differentiation is completed earlier than the female - at 16 or 20 weeks respectively, Hunt (1966) supposes that at the time of completion of sexual differentiation the developmental retardation attributable to the Y chromosome, begins to manifest itself in the males who are retarded by about four weeks at birth even though they are generally larger than the female.

B. Physical Growth and Maturation

At birth the human male exceeds the female in weight by approximately 5 per cent, with the disparity increasing to 20 per cent by the age of 20. Similarly in height the male's excess of 1 - 2 per cent at birth increases to approximately 10 per cent at 20 years of age (Anastasi, 1950). This greater height and weight of males at birth occurs in all races, ethnic groups, social classes and under all conditions of nutrition. Improvements in the standard of living, the dietary level, and the social class status tend to increase this discrepancy (Millis, 1955; Scheinfeld, 1965) due, as Tanner (1970) points out, to the principle of canalisation or homeorhesis, which states that if thrown off-course by adverse conditions the female's resumption of the normal course is speedier when such conditions are rectified.

In spite of her smaller size at birth, however, the newborn girl is actually a better developed organism, being approximately 4 to 6 weeks ahead of her male counterpart in developmental acceleration. This gap widens with age, with women reaching the terminal maturational stage at about the age of 21 and men at about the age of 24 (Scheinfeld, 1965). As Garai and Scheinfeld (1968) point out this maturational inequality of males and females at birth may actually obscure important sex differences. Since the girls are more mature than boys they would be expected to be more advanced in behavioural manifestations, and the absence of observed sex differences at birth may therefore conceal actually present sex differences in favour of boys.

Using many different parameters as indices of maturation, different researchers have found boys to lag behind girls in maturational development. Bone ossification (skeletal age) is completed 8 to 27 months later in boys than in girls (Pyle et al, 1961; Stuart et al, (1962), and they reach puberty about 15 months later than girls according to Nicolson and Hanley (1953), who also found that they attained their maximum growth rate 28 months later than girls (11.5 years vs. 13.8 years) with the difference decreasing thereafter. Bayley (1956) found that girls attained their adult height two years earlier than boys, this being some 5 to 6 inches less than the adult height of males. Using intrauterine growth rates as measured by X-rays, Flory (1935) found girls more mature physiologically by one year at school age, 1½ years by age 9, and 2 years at the onset of puberty. Girls were also more

advanced in dentition, acquisition of locomoter ability and completion
of physical growth. According to Darley and Winitz (1961), girls also
begin to talk earlier than boys by 2 to 6 weeks.

Males exhibit greater strength than females at all ages (Asmusson
and Heeboll - Nielsen, 1956; Meyers and Dingman, 1960; Terman and
Tyler, 1954). From early infancy on males display a stronger tendency
towards restlessness and vigorous overt activity, and this appears to
be related to their greater oxygen consumption required to fulfill the
need for increased energy production. The vital capacity of boys is
greater, especially after puberty (Asmusson and Heeboll-Nielsen, 1956;
Ferris and Smith, 1953). Boys develop proportionately larger hearts and
lungs (Tanner, 1970), have a lower resting heart rate (Iliff and Lee,
1952), but higher systolic blood pressure, particularly after puberty
(Shock, 1944), a higher concentration of haemoglobin (Shock, 1966) and a
greater capacity for neutralising such metabolites as lactic acid
(Tanner, 1970). Boys also have a greater dynamometric grip strength
although such differences remain small until the age of 18 to 20 (Asmussen
and Heeboll-Nielsen, 1956). All these characteristics make the male
better adapted for performance in vigorous and strenuous physical
activities and males have been found to be superior in such related
parameters as speed of movement (Hodgkins, 1963; Jensen and Fisher, 1972),
endurance (Morehouse and Miller, 1967), power and agility (Jensen and
Fisher, 1972), with little difference between the sexes until the onset
of puberty. By the age of 18 to 20 there is a vast male superiority in
vigorous athletic performance, the most outstanding female athletes
attaining approximately the performance standards of average or slightly
above average males. As Jones (1947) concludes, there can be little
doubt that sex differences in strength are genetic in origin.

Andersen (1966) has underlined the important metabolic effects of
the testicular androgen, which facilitates the synthesis of proteins
from amino acids and the retention of nitrogen, potassium, phosphorous
and calcium, increases the formation of cholesterol and free fatty acids,
and has a facilitatory action on muscle and bone development.
Oestrogens on the other hand bring about a decrease in serum cholesterol,
do not affect the nitrogen balance, do not have quite such a direct action
as the androgens on protein synthesis and result in an increase of
adipose tissue. These effects could account for the superior strength
and athletic performance of the male, and in view of what has already

been said concerning the possibility of biological factors influencing specific abilities and causing a bias of attention and interest in a particular modality, it is interesting to note that there is considerable evidence to indicate that from the pre-school years onwards, males prefer vigorous play involving muscular strength, dexterity and physical exertion with athletic prowess being considered an important asset at almost all stages of social development (Brace, 1954; Coleman, 1961; Garai and Scheinfeld, 1968).

The calorie intake in boys is greater than in girls from the second month on and from the ages of 2 to 7 years boys maintain 10 to 15 per cent higher calcium levels (Beal, 1961). Potassium needs are higher for boys from puberty onwards (Garai and Scheinfeld, 1968), probably as a result of the greater development of muscular and bone structures and the physical exertion accompanied by increased strength and vital capacity. Garai and Scheinfeld (1968) also point out that the recommended daily protein allowance for females is only 83 per cent of that recommended for males. In general the male organism appears to operate at higher levels of speed and intensity, and therefore requires a greater amount of fuel than the less active female organism. Males have a consistently higher basal metabolism from the age of 2 onwards (Lewis et al, 1943; Schock, 1955), and this difference on the Basic Metabolic Rate remains significant even after the sexes have been equated for body size, leading the investigators to the conclusion that the sex difference in basal heat production represents a metabolic difference which may be related to anabolic steroid hormones (Garn and Clark, 1953).

In spite of greater strength and athletic ability however, the male organism appears to be more vulnerable to stress, diseases and unfavourable environmental influences than the female organism (Scheinfeld, 1965). Throughout life all the major diseases affect males more severely than females with the exception of diabetes and cerebral haemorrhage (Garai and Scheinfeld, 1968). Geneticists ascribe the female's greater resistance to stress and most diseases to her biochemical advantages in various respects, and in the case of sex-linked conditions, to the special protection afforded her through having two X-chromosomes instead of the male's single one (Scheinfeld, 1965).

Reviewed in this section, then, is some of the evidence indicating the very obvious sex differences in many aspects of biological

development and biological functions. It would seem inconceivable that these differences have no impact on the psychological and behavioural functioning of the two sexes, and later sections of this chapter will provide examples of further differences between the sexes which may similarly be attributed to biological factors to a greater or lesser extent.

2. EARLY MANIFESTATIONS OF SEX DIFFERENCES IN RESPONSE TO AUDITORY AND VISUAL STIMULI

The earlier sex differences can be observed, the more likely is their origin genetic, since the effect of environmental factors is minimal in the early stages of development. Increasing sophistication in experimental design and controls has led to a series of studies furnishing reliable evidence of sex differences among neonates during the first five days of life, particularly in relation to the quantity and quality of spontaneous motor activity. Some investigators report no significant sex differences in motor activity (Balint, 1948; Brownfield, 1956; Kessen et al, 1961; Rosenblith, 1961), but other studies report that males are slightly more active than females at birth. (Bayley, 1965; Richards and Irwin, 1935; Rosenblith and De Lucia, 1963). A more recent study by Korner (1969) indicates that whilst the amount of motor activity occurring in males and females was the same (excluding erections) the type of activity was very different. In the male, motor activity was constituted primarily of startles, and took the form of relatively gross and massive movements, whereas in the female finer movements, circumscribed to the facial area, were predominant. Since erections are additional to these motor activities, males could, in fact, be said to display overall greater spontaneous activity at birth than females. Moreover, as Garai and Scheinfeld (1968) point out, in view of her advanced maturation at birth one would expect the female neonate to be ahead of the male, if activity motivation were equally distributed among the sexes. Thus the widely reported lack of a sex difference in motor activity at birth suggests an inherently greater activity drive in the male.

Where studies have investigated the vocalisation of infants, no sex differences have been found in the total amount of vocalisation produced, but again there have been differences in the type of vocalisations produced by the two sexes. There would appear to be little difference between the sexes in the rate of early babbling (Moss, 1967; Lewis, 1972), but some studies indicate that a significantly higher rate of

vocal interchange is discernible between mothers and daughters than between
mothers and sons (Goldberg and Lewis, 1972; McCall & Kagan, 1970;
Messer and Lewis, 1972). It has been suggested that this occurs as
a result of a complex interaction between the vocal behaviour of the
infant and the behaviour of the mother (Lewis, 1972). It was noted
that girls receive much less physical attention from the mother, an
observation also made by Moss (1967), and that girls appear to be
comforted more easily by 'distal' stimulation. Males on the other hand
appear to require physical comfort, and are not comforted by speech.
As stated, infants do not differ in the amount of vocalisation produced,
but Lewis found that mothers actually reinforce more of the vocalisations
produced by their male offspring than by female offspring. Despite
the lower level of reinforcement by the mother, however, a greater
proportion of female vocalisations were in response to maternal
behaviour, although Phillips (1973) reports that mothers do not appear
to speak more effectively to one sex than the other. In a complex series
of experiments, Phillips could find no differences at all in the number
and complexity of words per utterance to male and female infants aged 8,
18 and 28 months - posing some problems for differential reinforcement
arguments.

Differences have also been reported in some studies in the way in
which the sexes respond to different types of stimulus input. Indeed,
the proposal by Garai and Scheinfeld (1968) of a 'visual stimulus hunger'
for boys and an 'auditory stimulus hunger' for girls stems from this type
of study. For example, in a study of operant conditioning, in which
the potencies of auditory and visual reinforcers were investigated for males
and females, Watson (1969) found that at the age of 14 weeks, boys and
girls responded to operant conditioning of visual fixation. The
infants were rewarded for fixating on the presented stimulus with either
a visual or an auditory reward. The visual reward consisted of the
change of a white circle into an interesting coloured face, and the
auditory reward was a soft tone emanating from a speaker behind the
infant's head. Girls learned significantly only when presented with the
auditory reward, whereas the boys learned significantly only under
conditions of visual reward. This experiment has been one of the most
often cited studies in support of the view that the sexes have different
modality preferences. In two follow-up studies, however, these effects
were not replicated. Dorman et al. (1971) found better conditioning
of visual fixation with visual reinforcement for both sexes, while in
another study, Ramey and Watson (cited by Macoby and Jacklin, 1974) found

no conditioning in either sex with auditory reinforcement. This
highlights an important problem in considering sex differences in
modality preference - while some studies do present evidence indicating
that the sexes differ in their response and attention to auditory and
visual stimulation, the findings are far from consistent. Maccoby
and Jacklin (1974) cite numerous studies in which no differences between
the sexes have been revealed, and maintain therefore that the two
sexes are very similar in their interest in and utilisation of
information that comes to them via hearing and vision. Certainly,
differences between the sexes in most parameters are relatively small.
To deny their existence, however, fails to answer the problems posed
by those studies in which sex differences are revealed - and some studies
DO suggest that certain types of stimulus information are more salient
to one sex than the other.

One of the most consistent and stable results of all the research
relates to the female and the auditory modality. Female infants are
not only highly attentive to auditory input, they also appear to respond
to its emotional and meaningful properties. In a study in which the sound
of an infant's cry and white noise played at the same volume, was
presented to one-week-old infants Simner (1971) found that females were
significantly more discriminating than males in distinguishing between
the two sounds, although both sexes cried more in response to the
newborn's cry. However, it is important to note that Simner was unable
to obtain a consistent response on two occasions from the males. Kagan
and Lewis (1965), in a comprehensive study of infants at the ages of 24
weeks and 13 months, found that at the earlier age girls respond more to
a complex auditory stimulus (music) whilst the boys reacted more to a
single repetitive input of tones, and at the later age the same girls
consistently responded to verbal input with high inflection, with a
significant positive correlation between those who had high attention
levels to music at 24 weeks and those who paid the most attention to
the high inflection verbal input. Girls also vocalised significantly
more to the five types of auditory stimulus used, which included the
recorded voice of each infant's mother, and strange male and female
voices. Both boys and girls vocalised most at the presentation of
female voices.

In the case of visual stimuli, the evidence indicates a sex
difference in the category of input to which infants respond, and Fagan
(1972) suggests that this has nothing to do with the maturational factors

which apparently affect visual acuity. Faces are of considerable
interest to both sexes, but females appear to possess more discriminability
and show even greater interest than boys, whether exposed to masks
of faces, photographs or line drawings (Fagan, 1972; Lewis, 1969;
Lewis et al, 1966). In terms of smiling, vocalisation, or motor
activity responses to visual stimuli, Lewis also reports that females
appeared better able to discriminate between realistic and unrealistic
line drawings of faces, while Fagan found girls more able to discriminate
consistently between photographs of people of different ages and sex,
as well as between photographs of two very similar faces - an ability
not possessed by the boys in tests using photographs.

As a result of these findings it has been suggested that female
infants are more likely to respond to socially-orientated stimuli than
males, being able to discriminate more effectively between non-social
and socially affective stimuli, and to respond more appropriately to
such stimuli. Further support to this suggestion is given by the
findings of Moss and Robson (1968). Working with 3-month-old infants,
and using the amount of time spent viewing stimuli as an indication of
interest, they showed that a positive relationship exists between this
time and the amount of contact, stimulation or visual interaction with
the mother in female infants, but in males it related positively to
the time they spent quietly awake, and the social responses of the males
in no way achieved the same magnitude as those of females. A similar
sex difference in looking and social behaviour was noted by Mitchell and
Brandt (1970) in the rhesus monkey.

Boys, on the other hand, apparently are more attracted to such
varied stimuli as blinking lights, complex goemetric patterns, coloured
photographs of objects and three-dimensional objects (Cornell and Strauss,
1973; Kagan and Lewis, 1965; McCall and Kagan, 1970; Myers and Cantor,
1967; Pancratz and Cohen, 1970), habituating more efficiently to objects,
and producing more consistent orienting responses to novel objects than
girls. Even when presented with facial configurations as stimuli, boys
looked at them longer than girls (Lewis, 1969), and in terms of the
vocalisations produced, they appear not to differentiate between faces
and objects, but produce a significantly greater amount of vocalisation
when presented with blinking lights as a stimulus (Kagan and Lewis, 1965) -
it being postulated that vocalisation in boys is part of a spontaneous
motor outflow, reflecting interest. Support for this interpretation

comes from the findings of McCall and Kagan (1967). In their study, 4-month-old infants were shown a series of random patterns, and a high correlation was obtained between heart rate deceleration in response to a stimulus (indicating attention) and the production of vocalisation in males, but no such relationship was found for females. Lewis (1969) has used smiling responses as an indication of attention to different stimuli, and has noted similar differences, with males smiling equally in response to objects and faces, and females smiling only in response to faces. In a similar study McCall (1972) found that boys produced smiling responses to novel stimuli, a reaction not predictable for girls, who respond most when the stimuli presented are likely to smile and vocalise back, suggesting that the female infant responds more to functionally significant or meaningful stimuli, rather than to novelty.

As can be seen, these findings are of considerable significance when considering the proposal that differences between the sexes in modality preference might bias perceptual development, and influence the development of special cognitive abilities - particularly if differences in sensory sensitivity between the sexes can also be demonstrated. These will be discussed in the next section, but before doing so, it is important to point out the significance of the findings discussed here to the widely reported female superiority in verbal ability and language (see Garai and Scheinfeld, 1968). This has often been attributed to differential reinforcement behaviour by the mother in favour of the female. The evidence cited here provides little support for such a belief - indeed Lewis (1972) suggests that mothers actually reinforce more vocalisations by their male infants than by their female infants.

3. SEX DIFFERENCES IN SENSORY SENSITIVITY

Differences between the sexes in sensory sensitivity may provide some valuable information concerning the interaction between biological and socio-cultural factors. Such differences are likely to be biological in origin, particularly if they can be shown to be consistent between the sexes throughout life, and can be observed at an early stage of life. They may also be of considerable significance in explaining differences in other, more complex, central processes.

Several researchers have reported that female neonates are more sensitive to tactile stimulation and pain than male neonates (Bell and Costello, 1964; Lipsitt and Levy, 1959; Wolff, 1969), but negative

findings have also been reported (see Maccoby and Jacklin, 1974).
Lipsitt and Levy (1959) report a failure to replicate their findings,
while Gullicksen and Crowell (1964) could find no evidence of sex
differences. Similarly, in the visual and auditory modalities, such
evidence as does exist shows little effect of sex (Engel et al, 1968;
Eisenberg, 1972; Korner, 1970, 1971; Korner and Thoman, 1970). In
her later review Korner (1973) concludes that neonates are insufficiently
advanced to provide much useful information on differences in sensory
sensitivity, particularly in relation to the auditory and visual
modalities. This point is also made by Spears and Hohle (1967), who
point out that in the very young infant neither the eye nor the ear is
functional at any level approaching that of the adult. Visual acuity
is extremely poor, and binocular coordination is not evident until
about the sixth or seventh week of life. They also indicate that the
auditory threshold of the neonate is approximately 40 - 60 dB above the
normal adult level, which they attribute to the residue of connective
tissue in the middle ear. The problem is further exacerbated by the
fact that, as has already been pointed out, the female neonate is at a
maturational level some 4 to 6 weeks in advance of that of the male
(Garai and Scheinfeld, 1968). In consequence, where differences in
responsivity are found, though these are very small, the increased
sensitivity of the female may perhaps be more attributable to maturity
than to any particular sensory abilities.

In children and adults the evidence for female superiority in
tactile sensitivity is far more conclusive than that presented for
neonates. Axelrod (1959), Ippolitov (1972) and Weinstein and Sersen
(1961) all report an overwhelming superiority in females for sensitivity
in the fingers and hands, while the last study also reports a similar
sensitivity difference for the soles of the feet, but could find no
difference in forearm sensitivity. In these studies the differences
between the sexes are so great that there is often no overlap between
male and female scores. It has been suggested by Garai and Scheinfeld,
(1968) that these higher sensitivity levels in the fingers and hands
must contribute in some way to the superior abilities displayed by
females in some manual dexterity tasks (Annett, 1970; Tyler, 1965).

Sensitivity to temperature has been tested by Clark and Mehl (1971).
In a test of thermal threshold, using a group of elderly subjects over
the age of 65, they concluded that males were more sensitive to heat,
but at the same time were more able to tolerate thermal pain.

Sex differences in taste have been reported (see Garai and Scheinfeld, 1968) with conflicting results in relation to taste discrimination. In a study of under-graduate students, females were found to have more sensitive tastes for quinine and, probably, for sodium benzoate than males, although bitter and sour tastes are often hard to distinguish (Soltan and Bracken, 1958). Kaplan and Fischer (cited by Maccoby and Jacklin, 1974) similarly report that women are more sensitive to bitter tastes, while Nisbett and Gurwitz (1970) report that female neonates increase their sucking rates for sweet solutions, while males do not. This last finding, of course, does not reveal whether males are unable to discriminate between sweet and neutral solutions, or whether they discriminate but do not especially like the sweet taste.

Sex differences in taste have also been reported in animal studies. Among mature male and female rats, females showed a much greater preference for slightly sweet glucose and very sweet saccharin solutions than males. Males, when given a choice, changed from an initial preference for a saccharin solution to a preference for a glucose solution after several days, while females maintained a preference for a saccharin solution and also preferred significantly higher concentrations of saccharin than males (Valenstein et al, 1967). Evidence that this preference is biologically determined is provided by Zucker (1969) who reports that oestrogen injections in rats increased saccharin preference. Thus the evidence, though sparse, indicates that females are more sensitive to at least some tastes.

There is good reason to expect sex differences in the olfactory modality among human beings, with evidence regarding the sense of smell widely reported from the animal world. Sexual behaviour is frequently dependent upon olfactory discrimination, with the members of one sex secreting a sensuous odour to attract members of the other sex. In some species, the male exudes this sensuous odour to attract the female, but in most species the male requires greater olfactory discrimination to trace the presence of the female (von Frisch, 1963). Little evidence exists concerning the olfactory discrimination of human subjects, but there are reports that changes in oestrogen levels during the normal fluctuations of these hormones in women are associated with changes in the acuity of the sense of smell (Maccoby and Jacklin, 1974). Two studies of responsiveness to several odours among newborns found no sex

differences (Lipsitt and Jacklin 1971; Self et al, 1972), but
Moncrieff (1968) has provided evidence for differences in odour
preferences between the sexes both in adults and children, and
indicates that these preferences change with age.

In the auditory modality, studies on threshold for sound have
consistently shown superior hearing for high frequences in females
(levels of approximately 3,000 to 4,000 Hz and higher). The
difference between the sexes increases with higher frequencies and
with age (Corso, 1959; Eagles et al, 1963; Hull et al, 1971;
McGuinness, 1975). The most significant of these studies so far
as the effects of environmental factors on sensory sensitivity are concerned
is that of Corso, who originally set out to show that the difference
between the sexes could be directly attributed to the environment.
After eliminating all subjects who had even a remote experience with
environmental noise, or any history of hearing difficulties, he found
that there were still differences between the sexes, and that they were
slightly more pronounced than those he had originally found in the
total sample.

Tests involving responses to intensity demonstrate important and
consistent differences between the sexes in auditory sensitivity.
Using white noise, Elliott (1971) tested 64 children aged 5-6 and 10-11
years for tolerance of intensity and found that girls consistently set
lower volume levels at both ages. McGuinness (1975) reports similar
findings in a study with young adult subjects, who were asked to set
a volume of sound as just 'too loud'. The mean scores across all
frequencies were 75 dB for the females and 83dB for the males, and it
was suggested that, since loudness doubles subjectively at about
9 - 10 dB, at about the level of 85 dB, females will hear the volume
of any sound as twice as loud as males. In tests of simple auditory
perception, in which children aged 4 to 8 years were asked to judge
which aspect of an auditory stimulus was varying, Zaner et al, (1968)
found that girls were significantly more able to distinguish between
changes in intensity, but could distinguish no differences between the
sexes in their ability to notice changes in frequency, duration or
number of signals.

This greater sensitivity of females to auditory intensity is
probably related to their greater sensitivity to cues of laterality

(Pishkin and Shurley, 1965) and to their greater ability to locate
a sound source (Schaie et al, 1964), since Milner and Teuber (1968)
maintain that the localisation of sound is related to the detection of
intensity differences between the ears.

Sensory capacity in the visual modality also differs between the
sexes, with male superiority in photopic visual acuity for both static
and moving targets being well documented. Roberts (1964) using a
modified Snellen test, found that in a study of 6,672 subjects males were
less likely than females to be found at the poorer end of the scale,
and are more likely to have 6/6 vision or better. In investigations
by Burg and Hulbert (1961) and Burg (1966) of dynamic visual acuity in
adolescents, males were significantly better than females at identifying
the orientation of a checkerboard pattern in one corner of a moving square
at all velocities tested. This sex difference in visual acuity does
not appear to any marked extent, however, until adolescence. Skoff and
Pollack (1969) could find no differences between the sexes in Vernier
acuity for either black and white or coloured targets in a sample of
96 boys and girls aged 7 to 14 years. It is possible that foveal
acuity improves in males following puberty and could be due to increased
levels of testosterone (Andrew, 1972).

Evidence comparable to that presented for the auditory modality
is not available, although McGuinness (1975) does provide data
relating to threshold, intensity judgement, acuity and short term
memory processes in vision in young adults. She confirms the superiority
in visual acuity of males and also suggests that they are more sensitive
to light intensity than females. She concludes that men have superior
cone vision, but that females are more sensitive to tests performed in
the dark, adapting more rapidly and to lower threshold levels than men.
This superior performance in the dark was also found on the test of very-
short-term-memory, where women had significantly longer visual holding
than men. This difference disappeared entirely when the same test was
performed after light adaptation. In contrast to these findings, however,
Ippolitov (1972) has presented data suggesting that males are more
sensitive in tests of dark adaptation to visual threshold.

Other parameters within the visual modality reported to yield sex
differences are colour blindness, and peripheral vision to men (although
no evidence is presented to support this), whilst the difference in colour

blindness is reported by Garai and Scheinfeld (1968), with significantly greater numbers of males suffering colour blindness (particularly in red/green discrimination) than females, when measured by the Isihara test.

In certain visual phenomena sex differences have also been observed. Boys are more susceptible to experiencing rapid reversals in a reversible figures test over all ages (Garai and Scheinfeld, 1968; Immergluck and Mearini, 1969). The latter authors note that a high correlation was found for rate of reversals and performance on the Rod and Frame Test in a previous study on adults, indicating a link between experiencing rapid figural reversals and visual-spatial ability, that is, the ability to perceive relationships between shapes in space. In tests for thresholds for the PHI phenomenon (the apparent movement of two alternatively lit figures) women were found to have lower thresholds (Pohl and Caldwell, 1968), while early studies by Voth (1941) and Chaplin (1955) suggest that females also show less susceptibility to the autokinetic effect, where a stationary light appears to move in the dark. These findings were not, however, repeated in the more recent studies of Aranoff (1973) and Simpson and Vaught (1973).

Thus the evidence on sensory sensitivity, though sparse, indicates that very real differences exist between the sexes in virtually all modalities, with females possessing a certain advantage in some aspects of tactile and auditory processing, while males apparently have superior foveal vision (with the exception of colour sensitivity) - at least after puberty. The evidence also indicates that these differences tend to be consistent and enduring, and are to a large extent biogenetically determined, with the hormonal balance of androgens and oestrogens influencing the differences between the sexes in some parameters. That hormonal levels are implicated is further demonstrated by evidence obtained from studies of sensory sensitivity in females at different stages of the menstrual cycle. A number of studies have demonstrated changes of olfactory sensitivity during the menstrual cycle (Le Magnen, 1950; 1952; Vierling and Rock, 1967; Schneider and Wolf, 1955; Schneider et al, 1958), while Glanville and Kaplan (1965) recorded changes in sensitivity to the taste of quinine and thiouracil. In a study of pain threshold, Buzzelli et al, (1968) found that sensitivity was lowest around the time of ovulation, and Kenshalo (1970) demonstrated that detection threshold for temperature fell at ovulation and rose again at the onset of menstruation. Semazuk et al. (1967) present evidence

for the auditory modality which suggests that sensitivity is greatest around ovulation, a finding confirmed by Baker and Weiler (1977) for auditory threshold.   Pitch estimation was found to demonstrate a bi-mensual cycle, with lower frequency estimates at both around menstruation and around ovulation (Wynn, 1971; 1972).   In the visual modality, too, changes have been observed.   Diamond et al. (1972) demonstrated that sensitivity, measured by the ability to detect a patch of light in a slightly less illuminated background, was greatest at mid-cycle in normally menstruating females, and remained high until it declined abrputly at the onset of menstruation.   Males, and females taking an oral contraceptive, did not display the same cyclical fluctuations and were more sensitive visually than the normally menstruating group. Further discussion will be given to these findings in a later chapter.

4.   SEX DIFFERENCES IN ABILITIES

The literature reviewed thus far in this chapter has provided evidence for consistent trends in differences between the sexes in a number of parameters ranging from the biological development of the organism to differences in basic sensory capacities, and it has been suggested that the latter influence the difference observed in attention and attentional preferences between the sexes.   In this section a number of special abilities, cognitive and behavioural, displayed by the two sexes, are discussed which may be related to some of the previously mentioned sex differences.

From the previous discussion, at an age where infants are unlikely to have any real history of differential reinforcement, they apparently show an interest in some stimuli rather than others, and these stimuli would appear to relate to superior sensitivity in a specific modality. There is thus some justification for suggesting that attention is influenced by sensory capacity.   The importance of the discriminative capacity of the sensory channels has been emphasised by Lindsay (1970), who demonstrated that when signals are made difficult to discriminate, the amount of information processed is drastically reduced.   In studies of animal attention, it has been observed that certain stimulus cues are relevant in a particular learning situation, while others have little effect (Honig, 1970).   This phenomenon is referred to as 'cue salience', and whilst it is far less common to think of human attention and perception in these terms, evidence exists to support its relevance to the human situation with certain types of stimulus information being more salient to one sex than the other, and this salience relating to channel

efficiency and subsequently to the way in which the developing child seeks to control and interpret this environment (Garai and Scheinfeld, 1978; McGuinness, 1975). Performance is therefore influenced by the meaningfulness of the stimulus and the salience of the sensory input. In other words, if females consistently show superior sensitivity in the auditory modality and this affects the attention paid to auditory stimuli, it might well give them an advantage in the performance of skills based on auditory perception, such as musical or verbal ability, and one might expect a similar superiority for males in tasks based on visual input.

Support for this suggestion that modality preferences for auditory or visual stimulation is related to performance in some of the special abilities associated with males and females comes from a study by Rosner (1973). He identified individual differences among first and second grade school children in America in the competent use of information contained in visual versus auditory stimulus patterns, and found that the 'visual' children were better at arithmetic (usually associated with males), the 'auditory' children at reading (usually associated with females). He does not, however, report whether there are sex differences in the perceptual orientations he has identified, nor does he suggest that these perceptual orientations are necessarily linked to sensory sensitivity.

INTELLIGENCE

Whilst considerable evidence exists which show that either one sex or the other possesses greater ability on certain items or sub-tests within the numerous forms of IQ tests used, there is great controversy surrounding opinions of the intellectual capacities of males and females.

Certainly most intelligence test constructors have attempted to make their tests 'sex fair'. On the rationale that neither sex should be at a particular advantage or disadvantage, and since it was impossible to determine which items or sub-tests were inherently better indices of 'intelligence', test constructors attempted to make their tests comparable for both sexes by eliminating those tests which resulted in significant sex differences (Terman and Merrill 1937; Wechsler, 1941) or by counter-balancing the sub-tests favouring either sex to provide a similar overall IQ score as a measure of intelligence (Wechsler, 1958). The tests having been constructed to ensure that both males and females perform

equally well, it is scarcely surprising that no significant difference in the total IQ score averages has been found between the sexes - and consequently there is no necessity to compute separate norms for men and women.

Nevertheless many differences have been found in the way in which the sexes obtain their overall IQ, and performance in the subtests has shown marked sex differences. Since no way of measuring intelligence other than the presentation of definite questions and tasks has been devised, there is no way of knowing whether either sex is intellectually superior in any absolute sense: males appear to be superior in some respects and females in others. The exploration of these special abilities has proved to be more rewarding than the search for absolute differences, and it is to a discussion of these special abilities that we now turn.

A.   VERBAL ABILITIES

Females have been reported to possess greater verbal fluency than males from infancy on (Garai and Scheinfeld, 1968; Tyler, 1965) and it is suggested that girls demonstrate superior scholastic achievement in school as a result of their better verbal fluency in literature, essay writing, grammatical tasks and foreign language. Certainly women attain their greatest success in the field of writing (Scheinfeld, 1965).

Darley and Winitz (1961) observed that the onset of speech in girls was between one and six months earlier than in boys, due, they believe, to the earlier maturation of the speech organs. Girls have been observed to exhibit greater verbal fluency from the age of 12 months on, with the beginning of articulate speech (Irwin and Chen, 1946), through-out life. Garai and Scheinfeld (1968) have reviewed a number of studies which suggest that from the age of 18 months onwards girls make fewer grammatical errors than boys, and are superior in sentence complexity and sentence length. Girls are also reported to articulate more clearly than boys (Templin, 1957), and are less prone to such speech disturbances as stuttering and poor articulation (Bentzen, 1966; Scheinfeld, 1965). Girls also perform better than boys in spelling at school (Bennett et al, 1959; Clark, 1959; McGuire, 1961). A few studies have found girls possessing a larger vocabulary than boys in the early years of school life, but the majority of studies found boys superior in this aspect from the age of 3 years onwards in Britain, France and the United States (Garai and Scheinfeld, 1968).

A closer study of the evidence on language provides some interesting information. The precocity of girls in learning to speak has already been mentioned. Wellman et al. (1931) observed that during the pre-school years girls were superior in articulation, intelligibility, and approximation to adult speech sounds, yet Irwin and Chen (1946) found that there were no differences between the male and female infants in the number of phonemic types. In the first two months the infant was found to have, on average, 7.5 sounds which were extended by the age of 29-30 months to 27 of the 35 sounds present in adult speech. Both males and females began with similar values and maintained similar progress throughout the first year, after which girls tended to exceed the boys, but the differences were not statistically significant. Similar results were obtained by Harms and Spiker (1959).

In a comprehensive study by Moore (1967) aspects of language development were investigated in 41 boys and 35 girls during the first eight years of life. Measures of intelligence and linguistic development were taken at 6 months, 18 months, 3 years, 5 years and 8 years. The only significant difference was the superior speech quotient of the girls at the age of 18 months. In girls this score showed a significant correlation with the 6 months score and to a lesser extent to some of the measures at 3 years, and reliably predicted most later assessments. In boys, however, no such relationship was found, and the 6 months score predicted none of the later assessments, while the 18 months score predicted very little. In consequence Moore maintains that linguistic development runs a steadier course from an earlier age in the female.

Early linguistic measures (even at 18 months) were highly predictive of IQ at later ages in girls, with vocabulary and comprehension correlating most highly with IQ. In boys no relationship was established between linguistic measures and IQ and Moore concluded that non-verbal channels play a prominent part in the development of boys IQ, since their later intelligence is better predicted by IQ, which includes many non-verbal items. Boys' IQ's also showed much more erratic development over the 8 years than that of girls.

Moore suggests that because of their need to communicate, girls focus at an early age on developing linguistic skills. This need is, in turn, prescribed by their greater interest in personal relationships and their predilection for nurturant roles. Such an explanation seems

plausible and it is possible that the greater auditory sensitivity of
the females is similarly linked to language development, verbal ability
and the nurturant role.

B.   SOCIAL ABILITIES

The arguments put forward to support the claim that females have
more highly developed social sensitivity than males stem partly from
the belief already discussed, that even in infancy females respond to
other people with greater interest than males, and that the nurturance
role of the female is biologically determined.   Gray and Buffery (1971)
argue that the sex difference in emotional and cognitive behaviour among
mammalian species -

> "are all remote but necessary consequences of the same
> overriding fact: the division of labour between the
> sexes in reproductive behaviour".

Social 'intelligence' is difficult to measure, but women do appear to
develop this trait earlier than males, and to retain some superiority
over them in social interests throughout life (Garai and Scheinfeld,
1968), and it has been suggested that females tend to concentrate their
search for information more upon the area of interpersonal relationships
in their attempts to make social contacts.

There is certainly support in the data for the belief that girls
are interested in other people from a very early age, (Fagan, 1972; Lewis,
1969; Lewis et al, 1968; Simner, 1971).   In an observational study
of newcomers entering a play-group, McGrew (1972) reports that girls as
young as 3 years of age responded to new children with affection, interest
and comforting actions and verbalisations, whereas the boys largely
ignored them and excluded them from their games.   Similarly, Witryol
and Kaess (1957) found that girls appeared to have a better memory for
socially relevant input than boys, while in a study by Goodenough (1957)
girls aged 2 to 4 years appeared to have greater sensitivity to people
than boys - girls included more people in their drawings than boys, and
verbalised more about people in a test designed to elicit verbalization
from abstract stimuli (92 per cent of the girls talked about people
against only 38 per cent of the boys).   Oetzel (1967) lists 21 studies in
which girls and women appear to have a significantly greater interest in
people and social matters than males.

C. SPATIAL PERCEPTION AND MECHANICAL ABILITY

The superior performance of males in tasks which demand the perception and use of spatial relationships is well documented (Garai and Scheinfeld, 1968; Guilford, 1967; Tyler, 1965), and Buffery and Gray (1972) refer to extensive evidence to suggest that this superiority of of the male exists not only in the human species, but has also been noted in the laboratory rat. Barratt (1955) reported that in Thurstone's Primary Mental Abilities test, men had higher scores on all ten of Thurstone's spatial sub-tests, and were significantly superior on eight. Similarly in a table of studies using the WAIS and WISC sub-tests, Hutt (1972) has shown that males are superior on the object assembly test, and to a lesser degree in block design and picture completion.,

Spatial ability also correlates highly with mechanical ability measured by mazes, puzzle boxes and the assembly of small objects, all tasks in which boys surpass girls from pre-school age on (Allison, 1956; Leczner, 1965; Mollenkopf, 1957).   In the Bennett mechanical comprehension test males are superior at a high level of significance only one in every 20 girls exceeding the mean score the males (Bennett and Cruikshank, 1942).   In the mechanical reasoning sub-test of the DAT also the mean score of boys is 35 per cent higher than that scored by girls (Bennett et al, 1959).   The greater interest of boys in mechanical devices can be seen early in childhood when they appear more eager to assemble and dismantle mechanical toys and objects than girls, and it is likely that this tendency is reinforced more in boys by our culture, since in pencil and paper tests of mechanical aptitude, the scores of females more nearly approach those of males than on practical object assembly tests (Allison, 1956), and training on some mechanical tasks reduces the difference in performance between the sexes to some extent (Allison, 1956; Mollenkopf, 1957).   Males apparently also experience considerably less disorientation in real space, and have a better sense of direction than females (La Grone, 1969).

One of the aspects of spatial and mechanical ability in which males really excel seems to be the capacity to rotate or isolate visual images into new planes or combinations.   If, as has been suggested, mechanical problems are more easily solved by looking than by continuous manipulation, the visual salience of the male, already documented, may determine to a large extent his spatial and mechanical superiority.   If however the Piagetian theory that the internalisation of schemata occurs only after

considerable exploratory and manipulative behaviour is correct (see Flavell, 1963), the male's greater responsiveness to novelty and early manipulative skill (Garai and Scheinfeld, 1968) may give rise to his superior performance.

In studies of 'cognitive style', Witkin et al. (1962) investigated certain performances in males and females designed to reflect independence or dependence on the field, using the Rod and Frame Test (RFT) and the Embedded Figures Test (EFT). Sex differences were apparent from the age of 8 years on, boys and men being more easily able to adjust a luminous rod to the absolute vertical under various conditions of tilts of self and rod, and to disentangle a hidden geometric pattern from a larger pattern. Witkin and his associates interpreted these differences as meaning that males are more 'field-independent' - a cognitive style variable that was thought to reflect analytic ability. However, the EFT loads heavily on a spatial factor when it is included in a battery with other visual-spatial tests and it has been argued by Sherman (1967) and Bock and Kolakowski (1973) that it is the spatial component that is responsible for sex differences in performance on them. Macoby and Jacklin (1974) have argued the need for tasks which are not visuo-spatial but that do involve 'disembedding' to test Witkin's original premise. It is significant that in such a test devised for use with blind subjects Witkin et al. (1968) found no sex difference in tactual and auditory versions of the EFT, but in a tactile matchstick problem found girls superior - the opposite result to that obtained in the visual form of this task, thus providing further support for the theory of salience in sensory channels affecting cognitive abilities.

Another problem arising from an assessment of visuo-spatial differences between the sexes relates to the relative contributions of genetic and environmental components. Young children do not exhibit these differences to such a marked extent, and male superiority does not occur until mid-childhood or later (Garai and Scheinfeld, 1968; Kirshner, 1971; Oetzel, 1967; Witkin et al. 1962). The evidence suggests a developmental change due either to environmental or biological factors, with evidence for the latter becoming more convincing (Bock and Kolakowski, 1973; Buffery and Gray 1972). It is significant that the already documented male superiority in visual acuity similarly does not occur until mid-childhood.

D. MATHEMATICAL ABILITY

No significant differences between the sexes in mathematical ability have been reported at the lower age levels - kindergarten and below - where number tests involve simple counting or identification (Terman and Tyler, 1954), or on tests for all age levels where only 'mechanical' arithmetic is involved. Both sexes have been reported to show equal aptitude at both elementary and junior high school levels on the DAT factor N, the ability having to do with the manipulation of numbers (Bennett et al, 1959). It is solving problems with numbers and arithmetical reasoning that boys appear to manage more successfully than girls (Heilman, 1933; Ralston, 1962).

Buddeke (1960) suggests that boys use different abilities in solving mathematical problems from those used by girls. He reports that boys employ solutions utilising a recognition of broad relationships among content areas, whereas girls perceive direct relationships among the elements of a given area but tend to keep content areas relatively separate. Pettigrew (1958) similarly found that males typically use broader category estimates than females when asked to classify a variety of phenomena susceptible to quantitative or numerical classification, and this was significantly related to their higher mathematics scores - findings substantiated by Wallach and Caron (1959).

As might be expected from the already discussed male superiority in visual-spatial tasks, boys appear better able to integrate spatial cues in their solutions of mathematical, and in particular, geometric problems. Archer (1962) found that men performed better at geometrical tasks when supplied with clues relevant to the geometrical form, whereas women preferred clues that were irrelevant to the geometric form. Elkind's studies (1961; 1962) demonstrated that a significantly higher percentage of males than females had abstract concepts of volume. All these abilities seem also to be partly based on the male's greater spatial aptitude, which provides him with an advantage in geometrical and other areas requiring abstract conceptualisation of space.

THE DEVELOPMENT OF SEX DIFFERENCES IN COGNITIVE ABILITIES -
A SPECULATIVE DISCUSSION

This chapter has attempted to review some of the current literature demonstrating differences between the sexes. In essence, the evidence points to the existence of two organisms differentiating from the moment

of conception onwards, possessing different biological features different developmental rates, and showing at very early stages of development different interests in response characteristics and sensory sensitivities and different performance levels in skills and cognitive abilities. In the main, these differences are significant but relatively small, and there is considerable overlap between the sexes in most parameters.

In the previous chapter several different types of theory were discussed which attempted to provide explanations for the existence of sex differences particularly in relation to cognitive abilities. These theories were broadly divided into two categories - those which stressed socio-cultural influences and those which suggested that the differences between the sexes are biologically determined. Throughout this chapter a number of differences between the sexes have been outlined which can not adequately be explained in terms of socio-cultural hypotheses, and in particular the study by Thomas et al. (1969) using longitudinal methodology, which demonstrated that each infant has persistent, innate, temperamental traits which continue into adult life, has done much to dispel the belief that all behaviour is due to differential reinforcement by the parent. From the evidence presented in this chapter, it would appear difficult to deny that even very young infants have different sensitivities and biases and that certain of these show marked variation between the sexes, thus providing support for a more bio-determinist viewpoint

As stated earlier, bio-determinist hypotheses have their roots in man's evolutionary development and generally trace the different sex roles and abilities from the primary division of the sexes for reproduction (Gray and Buffery, 1971). Thus Wynne-Edwards (1962) has suggested that the two sexes have become further specialised in more general characteristics, the female for bearing and nurturing the young, and the male for obtaining food and protection - the traditional sex roles resulting from the division of labour in hunter-gatherer societies (Pilbeam, 1972). Leakey and Lewin (1977) develop this argument to explain the development of differences between men and women in visual-spatial and verbal skills. Relating their argument to that of hemisphere dominance, they point out that for much of his development man existed as a hunter-gatherer. The separate abilities may then well have developed through a process of natural selection as a result of the division of labour; the males, as hunters covering large tracts of land in search of their prey, would have been given an advantage by spatial perceptual traits, while the females who were less mobile,

particularly during pregnancy and periods of nurturing the young, acted as gatherers of fruits and berries and spent more time in a sociable camp atmosphere, engaged in the full-time education of children and therefore had a greater need for verbal skills.

Such theories may also offer an explanation for differences between the sexes in auditory and visual sensitivity, where these can be shown to exist. Thus the 'auditory stimulus hunger' of females, postulated by Garai and Scheinfeld (1968) might be expected to link with the development of superior verbal abilities in females, as might the 'visual stimulus hunger' postulated for males be associated with the development of visual-spatial abilities. In their insistence that abilities are essentially pre-determined, however, bio-determinist hypotheses make little allowance for the plasticity of neural tissue and disregard any interaction between the genetic material and the environment. Thus, acceptance of this type of explanation would suggest that the central mechanisms controlling the development of cognitive abilities might influence sensory mechanisms and sensitivities, and produce a modality bias, rather than the explanation that these mechanisms and sensitivities (which may be influenced by cultural factors) might also affect, in turn, the cognitive abilities. In the study by Thomas et al. (1969), mentioned earlier, stress was given to the interaction of both genetic and environmental factors in the development of individual differences, and it would seem that an interactive explanation should be sought when considering differences in behaviour between the sexes.

McGuinness (1975) has provided an explanation of this type. On the basis of her findings that males and females differ in their response to intensity in the visual and auditory modalities (with males being more sensitive in the visual modality and females more sensitive in the auditory modality), she has presented an explanation of how linguistic and visual-spatial abilities may be developed from initial sensory differences. Her central theme is that sensitivity to intensity (produced by the amplitude of the signal) determines a perceptual bias. The importance of intensity as a factor in deciding whether a stimulus will be registered in the nervous system is certainly well-documented (Sokolov, 1963; Berlyne, 1970; Pribram and McGuinness, 1975). A highly discriminable signal on one channel will produce greater attention by allotting a greater amount of central capacity to that input, which may in turn draw more attention to the modality as a whole.

This is especially likely to be true of intensity, according to McGuinness.

It is then argued that this perceptual bias, which is manifested in early response characteristics, influences the development of special cognitive abilities, so that females display superiority in some verbal skills and males score more highly in visual-spatial tasks (see Garai and Scheinfeld, 1968).

This explanation is in essence a complex amalgam drawing from a number of the theories previously outlined: developmental lag, hemisphere dominance, differences in sensory sensitivity and basic perceptual abilities, hormonal differences, and socio-cultural influences.

It has been suggested that sensory channels with the greatest efficiency or 'competence' will tend to dominate other channels (Pribram, 1971). Efficiency leads to an increase of the flow of information along these pathways, and in turn to an increase in the amount of attention paid to this input. Increasing attention, in turn, produces more efficient transmission in an apparently circular process. Thus innate potential directs experience because it is easier to acquire competence in learning about the environment using innately efficient mechanisms (but this does not preclude inefficient mechanisms being made more efficient). In addition, a highly discriminable signal on one channel will produce greater attention by allotting a greater amount of central capacity to that input, which may, in turn, draw more attention to the modality as a whole. One important factor in deciding whether a stimulus will be registered in the nervous system is intensity (Sokolov, 1963; Berlyne, 1970; Pribram and McGuinness, 1975), and another is novelty.

The female has been shown to be less tolerant than males of high levels of auditory intensity (McGuinness, 1975; Elliott, 1971). This greater sensitivity to intensity (which is closely related to performance in verbal abilities - see Chapter 6) may also be manifested in the ability to detect small changes in intensity and in softer auditory stimuli attracting their attention. Thus, the sensitivity of the female infant to intensity may direct her attention primarily to auditory input (Kagan and Lewis, 1965; Watson, 1969), and in particular to emotional overtones in speech and music, since it has been argued that such overtones

are associated with intensity changes (Shuter, 1968; McGuinness, 1975).
Speech may then develop faster in the female infant, who evokes more
maternal verbal responses than her male counterpart by directing babbling
to her mother (Goldberg and Lewis, 1972; McCall, 1972; Messer and Lewis
1972). The development of speech may also be enhanced by the female's
interest in socially-oriented stimuli - an interest in people rather
than objects which is manifest early in life (Fagan, 1972; Lewis, 1969;
Lewis et al, 1966) and is presumably linked to the traditional nurturant
role of the female. Moreover, Buffery and Gray (1972) assert that an
innate,lateralised (usually left-sided) neural mechanism, which is
specialised for the extraction of certain linguistic features of speech
perception, develops earlier in the female brain than in the male, thereby
facilitating the development of linguistic skill in women.

There is good reason to believe that the human sex difference in
visual-spatial abilities is under the control of the sex chromosomes
(Buffery and Gray, 1972). More particularly, there is evidence to
suggest that a recessive gene determining superior visual-spatial ability
is carried on the X chromosome (Stafford, 1961; Gorah, 1965; Hartlage,
1970), with approximately 50 per cent of males and 25 per cent of
females possessing this superior ability (Bock, cited by Garron, 1970).
Buffery and Gray suggest that male superiority in visual-spatial
abilities are an indirect consequence of the early lateralisation of
the usually left-sided cerebral dominance for language function in females.
They propose that a more bi-lateral (though usually predominantly right-
sided) cerebral representation for non-verbal function is established in
the male than in the female brain, and such functional topography
facilitates the development of spatial skills.

Earlier in this chapter evidence was presented indicating that males
appear to respond more to the visual than females, displaying a tendency
to reinforce visual information with tactual and manipulative motor
activity from an early age. They show more interest in objects
(particularly geometric, brightly-coloured, three-dimensional objects)
and blinking lights (Cornell and Strauss, 1973; Kagan and Lewis, 1965;
McCall and Kagan, 1970; Myers and Cantor, 1967; Pancratz and Cohen, 1970).
Novel visual input gives rise to responses ranging from spontaneous
vocalisations in infancy (Kagan and Lewis, 1965; McCall and Kagan, 1967)
to manipulation and investigation (Garai and Scheinfeld, 1968). At a
later age they are able to solve restructuring problems more quickly than
females (Hutt, 1972). By puberty much of this behaviour is internalised

and visual-spatial problems are solved without manipulation (Bennett et al. 1959). The mechanical interest which is predominantly found in males occurs as early as 4 to 5 months of age (Garai and Scheinfeld, 1968). After puberty they possess keen visual acuity (Burg and Hulbert, 1961; Burg, 1966; Roberts, 1964, Skoff and Pollack, 1969) and fast efficient responses which correspond to their increasing physical strength (Hodgkins, 1963; Jensen and Fisher, 1972). It is suggested that all of these interact with cultural influences and manifest themselves in the well-documented superior visual-spatial and mechanical abilities of the male.

It is difficult to assign the greater response of the male to visual input to any one sensory parameter in the visual modality. There is a lack of research evidence on visual sensory sensitivity in young children, and as previously discussed, evidence for young adults provides conflicting or non-significant results for threshold and intensity. In the only parameter where considerable consistent evidence exists for a sex difference, namely visual acuity, evidence suggests that this difference does not occur until the mid-teens (Skoff and Pollack, 1969; Fagan, 1972), and may therefore be related to high levels of testosterone in the male (Andrew, 1972). McGuinness (1975), whose findings indicated that males were more sensitive to visual intensity than females, has argued that the attraction for young males of visual objects and blinking lights may stem from the perception of sharp contrasts between various planes and surfaces. This is supported by Berlyne (1970) who found that orienting and choice behaviour for visual input is determined by brightness and contrast. This then gives rise to a perceptual bias for the visual modality in males, in much the same way as it is suggested sensitivity to auditory intensity may do in females. However, McGuinness bases her findings on the results obtained when her subjects (20 males and 20 females) were asked to look directly at a light source and adjust it to a level of light which they felt could be looked at "without discomfort for an indefinite period". The methodology employed would seem open to question on two main counts. First, the apparent subjectivity in interpretation of the words "without discomfort for an indefinite period", and second since we usually respond to light which is reflected by objects in the immediate environment rather than to direct light stimulation, measurements of visual discomfort are usually related to glare (Hopkinson, 1963). These criticisms, together with the relatively small number of subjects tested, make it impossible to accept McGuinness'

hypothesis without further research.

The research reviewed in this chapter, while suggesting that different sensitivities and capacities might exist in the visual and auditory modalities for males and females, are incomplete with respect to many problems. First, the existence of a consistent and enduring pattern for many of the processes has not been established, since there have been few investigations of the adult, and developmental effects may not entirely be ruled out. Secondly, little research exists which attempts to determine whether the female's advantage in certain auditory tests is represented by consistent performance for individuals between tests. Yet by understanding how the sensory channels relate to one another, one is better able to determine which aspects of sensory differences are important in subsequent processing. For example, if the sexes are distinguished more reliably by a test of intensity judgement than any other parameter, the plausibility of the suggestion that intensity may be an important component of auditory skills in which females excel, proposed by McGuinness, becomes somewhat greater.

Further experimental support for the proposal could be obtained by establishing for a given group of subjects a significant relationship between performance in the auditory and visual modalities (particularly in relation to the tolerance of intensity) and performance in those cognitive abilities in which the sexes are reported to differ. It is the investigation of these issues to which we turn in the ensuing chapters.

NOTE:

This review of the literature and the conclusions drawn from it reflected the state of knowledge at the beginning of 1980. The collection and analysis of data, which was extended by a break in the time available for study, coincided with a considerable increase in research interest in the area of sex differences. A brief review of the research undertaken since 1980, however, requires no substantial alteration to the conclusions drawn in this chapter.

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CHAPTER 3

THE MEASUREMENT OF AUDITORY AND VISUAL SENSITIVITY

INTRODUCTION

In this chapter we are concerned with the basic problems facing the researcher into sensory sensitivity, namely what parameters to test and how they can best be tested. So far as the latter is concerned, the techniques used in this study have been borrowed from the field of psychophysics in either a direct or a modified form. Psychophysics may be narrowly defined as the study of the relationships that obtain betwea the various sensory attributes, for example the pitch of a tone, and the dimensions of the physical objects or events with which these attributes are associated, for example the frequency and intensity of the tone. Stevens (1957; 1961) has used the term methetic to refer to the former, or quality, stimulus dimension, and prothetic for the second, or intensity, dimension. Thus in the visual system, colour and location in visual space are methetic, and brightness prothetic.

Psychophysics evolved from early attempts to piece together the total perceptual experience of an individual by measuring and recording his experience. As indicated in a previous chapter, such an approach has both its limitations and its dangers, but in the light of the knowledge now available from the field of neurophysiology, and the more advanced behavioural studies of perception, information obtained using psychophysical methods might provide a new insight into the perceptual process. This argument will be developed further in a later chapter.

It has already been stated that one of the aims of this study is to compare the performance of males and females in both the auditory and visual modalities. This involves a comparison both within and between the two sensory modalities, and consequently to a large extent predetermines the types of measurement that may be used. For comparison within a modality, one should attempt to test and measure the different types of response mechanisms, such as discrimination, intensity and so forth, in an attempt to determine whether or not a sensory advantage in one test within a particular modality bears any relationship to performance in other tests in the same modality. For example, evidence already presented suggests that females have lower thresholds for high frequency tones (Corso, 1959) and that they are more sensitive to intensity differences (Pishkin and Shurley, 1965). Thus one must ask whether females will

excel in other auditory tests, and whether ability in one test bears any relationship to ability in another, thereby providing information concerning the qualitative unity of that particular modality.

Cross-modal comparisons of the two groups will provide information of a different kind. If a consistent relationship between sensitivity in the two modalities can be traced, information is provided relating to some general characteristics of neural function unique to each individual, giving some support to the type of theory put forward by Eysenck (1967) for the personality trait of extraversion - introversion.

In order to make such cross-modal comparisons realistic, one should attempt to match both the parameters and techniques in each of the two modalities. Because the sensory systems perform different operations on different forms of stimulus energy, however, the choice of measure is not always straightforward, and an exact replication of task is not possible. The problem is a two-dimensional one, involving both the properties of the stimulus and the type of operation performed by the subject. In the first case, parameters of the stimulus like intensity or frequency are altered in some regular fashion, while in the latter, the individual is required to detect either the presence of a stimulus (threshold), or the difference between two or more stimuli (discrimination) or decide between certain intensity aspects of a stimulus (qualitative judgement). Combining these two aspects largely determines which measures have some degree of compatability between the auditory and visual modes, so that the parameters tested in this study are those already outlined - threshold, discrimination (metathetic dimensions) and qualitative judgement (a prothetic dimension), and the rest of this chapter involves a consideration of these parameters within the two modalities, their relationship to each other, and the types of measurement techniques employed.

THE AUDITORY SYSTEM

1. Sensory Capacity: The stimulus for hearing is the physical change of a medium produced by vibration or mechanical disturbance. A sound wave is a vibration or disturbance travelling through a medium that distends in wave form in response to the disturbance. Naturally the speed with which the wave form is propagated depends on the density of the medium - the denser the medium, the faster the wave will travel.

Because the distension of the medium causes friction, this wave form
is not propagated indefinitely; rather, the amount of disturbance
decreases slightly on each successive swing as one moves farther from
the source of the sound.   These waves of sound are referred to as
'dampened' or 'attenuating sinusoids'.   Decreasing the magnitude of
the swing represents a reduction in the intensity of the sound wave.
'Amplitude' is defined physically as the highest point of deflection
of the wave from the base level equilibrium of the conducting medium,
and thus relates directly to the intensity of the sound.   The number
of completed positive and negative displacements of the medium over a
given period of time represents the 'frequency' of the sound wave.
This was traditionally measured in cycles per second (cps), but the
Hertz (Hz) is now accepted as the international unit of frequency
measurement (1 Hz = 1cps).

When the frequency of a sound wave is varied, the listener
experiences a change in 'pitch', whereas changes in the amplitude of a
sound wave produce perceived variations in loudness.   As stated earlier,
the relationships between pitch and frequency and between loudness and
intensity are examples of psychophysical functions - relationships
between psychological or behavioural judgements of stimuli and the
physical characteristics of stimuli.

The relationship between frequency and the perceived pitch of
sound tends to be logarithmic rather than linear, and a subjective
scale of pitch - the 'mel' scale - has been developed by Stevens,
Volkmann and Newman (1937).   For tones below 1,000 Hz, as the frequency
of the tone increases there is a disproportionate increase in perceived
pitch.   From 1,000 Hz to 4,000 Hz, the range of maximum sensitivity
for human observers, the relationship in linear, but for frequencies
above 4,000 Hz, a disproportionate change in pitch is again found.

The human ear is sensitive to sounds over a range of approximately
16 to 22,000 Hz, but individual differences are great.   The great
majority of sounds encountered in everyday life, however, display
frequencies from the lower portion of the sound spectrum - for example,
in music tones range from approximately 65 to 4,000 Hz (Murch, 1973).

A similar dichotomy exists between the physical and subjective
scales in the case of sound intensity.   The relationship between the

judged loudness (subjective measure) of a tone and the amount of physical
energy in the tone is approximately logarithmic. This relationship led
to the development of the decibel (dB) scale for measuring sound intensity.
The decibel scale is based on the logarithm of sound energy level
(actually ten times the logarithm of the ratio of a given sound energy
to the lowest threshold of the sound energy). Thus the judged loud-
ness of a sound corresponds in an approximately linear fashion with the
decibel scale of sound intensity. A subjective description of the
decibel scale is that loudness doubles at about 10 dB.

Threshold for the detection of sound can vary from -10 dB at 1,000
Hz to 40-50 dB at very high frequency levels. (Audiometric zero
is referenced to 2×10^{-5} N / m^2). Because the ear is more sensitive
in the region of 1,000 Hz and less sensitive to either low or high
frequency input, the audiometric curve is U-shaped. The performance
of both the normal and abnormal ear across various ages has been reviewed
by Corso (1959) and Christman (1971).

2. Receptor Processes: Good descriptions of the anatomy of the auditory
system are to be found in Stevens and Davis (1938) and von Bekesy (1956).
Briefly, the external auditory canal ends in the tympanic membrane, which
connects (via two small muscles, the tensor typani and the stapedius)
through the three small ossicles of the middle ear to a membrane
covering the end of a coiled tube called the cochlea. The tube of the
cochlea is filled with fluid and contains within it a smaller tube, the
cochlear duct, which in turn contains the sense organ, or organ of Corti.
Sound vibrations transmitted through the ossicles cause movement of the
fluid, producing vibrations of the basilar membrane, a rather stiff
membrane which bends relative to the tectorial membrane, thus bending and
activating hair cell receptors lying between. These receptors are
innervated by fibres of the auditory nerve, whose cell bodies lie in the
spiral ganglion embedded in the skull. Axons of these fibres enter
the Central Nervous System and synapse in the dorsal and ventral cochlear
nuclei in the medulla. Each auditory nerve has approximately 28,000
fibres and allows for the discriminability of some 340,000 single tones,
and approximately the same total number of single visual stimuli are
discernible on the basis of wavelength (frequency) and intensity of
light.

Identification of the particular aspects of receptor and neural

processes that determine various aspects of sensory experience or behaviour is one of the fundamental goals in the analysis of sensory processes. The absolute loudness threshold is a good case in point. In humans, the total range of frequencies is, as already stated, from 16 to 22,000 Hz, with the ear most sensitive to tones between 1,000 to 4,000 Hz. As the frequency is increased or decreased away from this region, increasingly greater sound energy is required to make the tone audible. Several lines of evidence (Davis, 1959) indicates that physical characteristics of the external and middle ear structures such as elasticity and inertia determine the form of the frequency threshold curve.

The acoustical and mechanical properties of the ear canal, ear drum and the middle ear bones determine the efficiency with which sounds of various frequencies are converted to mechanical vibrations and transmitted to the cochlea. This in turn determines the absolute threshold curve, thus, in general, in mammals the size of an animal appears to influence its threshold curve (Thompson, 1964). These factors may have some relevance in explaining the reported existence of differences between the sexes in auditory sensitivity, as may the findings of Corso (1967), that the audiogram curve is often very much the same for the various members of the same family, which he suggests is possibly connected in some way with the similarity in the shape of the face.

Movements of the basilar membrane in the cochlea to auditory stimuli were analysed by von Bekesy (1947), who showed that if a tone of a given frequency is presented, a travelling wave of fluid is set up in the cochlea which causes maximum displacement in a given region of the basilar membrane. Location of this maximum displacement on the membrane is related to the frequency of the tone. Due to the differential stiffness of the membrane, some rather complex mechanical effects occur, but the net result is that high-frequency tones selectively distort the regions of the basilar membrane close to the base of the cochlea, intermediate tones distort the base to intermediate region, and low frequency tones distort the whole membrane. Thus the cochlea acts as a complex mechanical analyser of an auditory stimulus - the region of the greatest distortion of the basiler membrane produces the greatest amount of bending of the hair cells and consequently the greatest differential activation of the auditory nerve fibres.

Historically, there were two major theories of auditory pitch
discrimination.   The first, Helmholtz's 'place' theory, assumes each
tone frequency activates a different portion of the auditory receptor,
whilst the second, or 'frequency' theory, proposes that the frequency
of a tone is reflected in the frequency of auditory nerve fibre discharges.
The research of von Bekesy (1947), Miller and Taylor (1948), and Wever
(1949) suggest that both place of excitation on the basilar membrane
and the frequency of the nerve responses are important in coding tone
frequency.   For high frequencies, place is most important but for
lower frequencies (below 4,000 Hz) synchronous discharges in nerve
fibres also play a role (see von Bekesy, 1956; Davis, 1959; 1961).

3.   Auditory Measurements:

A   Threshold: Standardised tests for the measurement of auditory
threshold have developed from the clinician's need to assess the degree
of deafness of an individual across a wide frequency range.   The
classic method for determining hearing loss has always employed the
method of limits, in which the volume level at which sound disappears
and reappears during a series of descending and ascending trials is
tested.   The apparatus required for such a test consists simply of a
variable sound source of oscillator coupled to an attenuator which
varies the intensity of the output along some calibrated continuum, usually
in decimbels, SPL, referenced to 2×10^{-5} N/m^2.   The modern audiometer
consists of just such apparatus – an oscillator and attenuator coupled
to a set of headphones which are matched in resistance to the attenuator.
This apparatus can then be very precisely calibrated across a wide
range of frequencies using an 'artificial ear'.

In 1955, the American and British Standards Associations set up
the International Organisation for Standardisation.   By combining data
from thirteen countries, agreement was reached on an audiometric zero
(level of 'normal' hearing) and calibration figures for frequencies from
125 Hz to 8,000 Hz.   This provides a valuable and highly refined
technique for measuring auditory threshold, and a considerable amount
of data has now been accumulated on hearing thresholds related to both
age and sex (Corso, 1959; 1963; 1965; Eagles et al, 1963; Hul et al.
1971; McGuinness, 1975).   In an attempt to relate to this data, and
because it provides an acceptable standardized procedure the audiometric
approach using the method of limits was adopted for this research.   An
excellent description of the methodology and problems involved in this

technique has been provided by Hinchcliffe and Littler (1958).

B.   Judgement of Intensity: Intensity judgements of loudness may be
made using essentially the same audiometric apparatus described in the
preceding section.   Considerable methodological problems confront the
researcher, however, when attempting to determine individual subjective
responses to intensity.   Two major approaches to obtain such information
exist.   The first uses a method of scaling in which the subject makes
estimations of magnitude about a series of randomly presented stimuli
which vary in intensity.   The second method is used in conjunction
with audiometry to measure the recruitment effect.   Loudness recruitment
is often a concomitant of a certain type of nerve deafness in which
thresholds are elevated and the subject experiences a rapid rise in
intensity at low decibel levels (von Bekesy, 1947; Dix et al, 1948).
These types of measurement are termed 'comfortable' or 'uncomfortable'
loudness levels, and these have been investigated in normal subjects to
determine whether or not recruitment is the natural result of any
elevated threshold (Hood, 1968; Schneider et al, 1972).   In this
method, the experimenter alters the intensity of input to coincide with
the subject's criterion of comfortable or uncomfortable.   As a
technique, it has had only a qualified success, primarily because of
the contamination of the response by anxiety (Stephens, 1970; Stephens
and Anderson, 1971).   Subjects may misinterpret the instructions and
assume that it is a test of tolerance, causing some highly anxious
subjects to become disturbed when the experimenter begins to increase
the volume, while others attempt to withstand quite painful levels.   In
an attempt to overcome this problem, McGuinness (1975) modified the
method so that the subjects manipulated the controls, having previously
been given a precise verbal loudness scale against which they were able
to match their criterion of comfortable loudness.

The first approach was discarded in this study since it is
immensely time consuming - the subject needs repeated trials for one
frequency alone.   In order to test a large number of subjects over a
range of frequencies, and to provide data which would compare with that
obtained in other studies the uncomfortable loudness test was used,
modified to include the precise verbal rating scale outlined by McGuinness,
but for practical reasons (the audiometer was outside the booth in which
the subject sat) and to ensure that the subjects had no feedback over
the series of trials from seeing the setting of the dials on each test,

the procedure of control by the experimenter was reverted to. Further discussion of the method used will be given in the next section.

C.   Pitch Discrimination: The most useful method of determining ability in the judgement of pitch has to involve memory, since modulating from one frequency to another produces an unmistakable 'sliding' effect. Provided the two stimuli to be compared are presented within a 1 - 2 second period, however, this is not a critical difficulty, since echoic memory lasts approximately 2 seconds (Neisser, 1967), ensuring that the neurological trace of the first stimulus is still available when the second is sounded.

The classical technique for any discrimination test is the constant stimulus difference method, which involves the comparison of pairs of stimuli, varying along a particular dimension and presented randomly, and the smallest 50 per cent level of a consistent detectable change is described as 'just noticeable difference' (jnd). Studies providing information on pitch discrimination tend to fall into two categories. The first are highly controlled psychophysical studies which concentrate on a small number of subjects and provide no normative data - and seldom control for musical training (for example, Henning, 1966; Delse et al, 1972). The second come from work on musical aptitude. These studies do provide normative data, but do not report on sex differences (Bentley, 1966). McGuinness (1975), however, has performed a psychophysical study, using a large number of subjects, controlled for musical ability, to test for differences between the sexes in the ability to discriminate between small frequency changes. A modified version of her described procedure has been adopted for this study.

THE VISUAL SYSTEM.

1.   Sensory Capacity: The present concept of light, the stimulus for vision, is very similar to that proposed by Newton in his 'corpuscular theory of light' in 1704, in which light was described as a stream of particles travelling in a straight line. In the nineteenth century Maxwell's 'electromagnetic theory' described light as a change in an electromagnetic field surrounding the particles, which is generated by the oscillation of the charged particles and travels through space as an independent entity. Modern physics still holds that such postulated relationships between light and electromagnetism are essentially correct. Modern quantum mechanics holds that all matter, including light, can be

described as a stream of particles, which in the case of light are
known as photons.

The two physical properties of light of primary interest in the
study of sensory capacity are wavelength and intensity (and in this
respect there is a close comparison between the visual and auditory
systems). Wavelength is the measure of the physical distance between
the peaks of the photon waves. It derives from and is inverse proportion
to the momentum of its photons, which in turn is a function of the energy
of its particles. Intensity of light, on the other hand, depends on
the number of photons in a particular light beam and on the highest
point (peak amplitude) in the wave motion of the particles.

As with the ear, the human eye is sensitive to only a comparatively
small portion of the wide spectrum of radiant energies. Visual
sensations are evoked by photon waves with lengths between approximately
420 and 700nm. Immediately above the visible spectrum are infra-red
rays, and below are ultra-violet rays.

A major difference between visual and auditory sensory responsivity,
however, is that we seldom respond to direct light stimulation. Rather,
light is reflected by objects and thus transmits information about
certain characteristics of those objects. Light strikes matter and
this causes a sympathetic response. Some of the light is re-emitted
by the object in the form of photons and these are picked up by the eye.
This light transmits information about the shape, texture and colour of
the object, providing the stimulus for a specific visual sensation,
activating the two different types of visual receptor - the rods and the
cones.

Numerous studies on vision support a 'duplexity theory of vision'
(Corso, 1967). Rods function at low intensities and initiate colourless,
achromatic vision (scotopic vision); cones operate at higher intensities
and are responsible for mediating colour responses (photopic vision).
There is a wide range of intensities between the weakest light that can
produce a threshold response in the rods and the strongest light that can
be tolerated by the cones.

It has been estimated that a single quantum of light can excite a
rod, though it usually requires approximately 50 or more quanta to produce

a sensation of seeing (Graham, 1965; Cornsweet, 1972). Expressed in terms of luminance, minimal threshold for dark-adapted rods for white light with relatively long exposure is approximately 0.000001 millilamberts, for cones 0.01 millilamberts, while the terminal threshold, or upper limit of visual tolerance, occurs at approximately 16,000 millilamberts (Corso, 1967). As in audition, intensity is measured using a logarithmic scale.

Colour vision, or hue, is a sensory characteristic of cone vision related primarily to wavelength, with 400 ηm representing the blue or violet end of the spectrum, through green (490-570 ηm) and yellow (570-600 ηm), to the oranges and reds (600-700 ηm). Hue is not a property of electromagnetic energy, but is a characteristic or dimension of experience that depends upon the normal functioning of the visual system. Because colour vision is a function of the cones, which are concentrated in the centre of the receptive field (fovea), peripheral vision is largely insensitive to colour and results from the activation of the rods, which are maximally sensitive at about 20° of the visual angle. The rods are effectively blind to any red light, a peculiarity of the eye that makes it possible to dark adapt completely when only exposed to red light.

It is apparent that the visual and auditory systems do bear some relationship to each other when considering the sensory processes in terms of threshold or responses to changes in intensity, but they are very different in terms of the transduction of energy. Changes in wavelength of sound bring about a change in pitch, but changes in the wavelength of light result in a shift of colour. Similarly, the term 'discrimination' refers to different types of experiment in the auditory and visual modalities. The typical discrimination task in hearing is the detection of differences in pitch, whereas in vision discrimination can refer either to tests of visual acuity, or tests of colour (frequency) discrimination. Furthermore, in visual discrimination tests, presentation is spatial, and stimuli appear concurrently with little temporal restriction, while the comparison of two simultaneous stimuli are not possible in any precise fashion in audition (Christmas, 1971; Tobias, 1965).

2. Receptor Processes: The differentiation of structure and function in the two basic types of photoreceptor cells in the retina of the eye is of fundamental importance. The centre of the visual field, that

is the region we see most clearly when we look at an object, projects upon the fovea, composed entirely of cones. Foveal cones have an almost one-to-one relation to outgoing nerve fibres. The rods have their greatest density about 20° of the visual angle away from the fovea. There are approximately 125 million rods and 6 million cones in the human retina, but only about 1 million optic nerve fibres. Hence receptors will activate each nerve fibre, particularly in the peripheral regions of the retina where the rods predominate.

At least two visual pigments (chemicals responsive to light) can be found in the receptor cells of the mammalian retina - rhodopsin in rods and iodopsin in cones. When light falls on a rod, rhodopsin immediately breaks down into retinine and opsin. Retinine has a relatively simple chemical structure closely related to Vitamin A, which is associated with night vision, and opsin is a complex protein (Wald, 1959). Two different chemical pathways exist whereby rhodopsin can be resynthesised, either from retinine and opsin, or from Vitamin A back to retinine and then combination with opsin.

The visual pigment of the cones, iodopsin, breaks down upon exposure to light into two substances - retinine, in the same form as that obtained from rhodopsin, and a different protein - photopsin. Thus the visual pigments of both the rods and the cones consist of retinine and a protein, with only the protein differing, and the chemical reaction of both are comparable.

There are in fact more than two visual pigments in vertebrates, depending upon the species, and whether the receptor is a rod or cone, but in all cases the pigment is composed of retinine and a type of protein opsin. In human rods there is one rhodopsin, composed of neo-b-retinine and a particular opsin, and in human cones there are three iodopsine, the latter being made up of neo-b-retinine and three different opsins (Wald, 1961). Stiles (1961), Rushton (1961) and Wald (1961) have provided some strong indirect evidence concerning the absorption spectra (wavelengths of light that are absorbed) of the three types of iodopsin found in human cones, suggesting that there are three types of cone pigments, with absorption maxima at about 440 nm (blue), 540 nm (green) and 590 nm (red), thus providing support for the three receptor theory of colour vision first propounded by Thomas Young in 1802.

The complicated chemical processes involved in vision again

differentiate it from audition, which may be seen as essentially a mechanical process. A number of aspects of visual sensation, particularly relating to brightness and colour phenomena, can be deduced very accurately from the biochemical properties of the iodopsins and rhodopsin. Foremost among these is the virtually perfect correspondence between the spectral sensitivities for rod and cone vision and the absorption spectra of the rod and cone pigments. Another striking correspondence concerns the time courses of rod and cone dark adaptation. If the eye is exposed to bright light, it requires up to 30 minutes for the rods to re-establish maximum sensitivity. The spontaneous rate of synthesis of rhodopsin in solution follows virtually the same curve as does the rate of rod dark adaptation. Cone dark adaptation is much more rapid, requiring about six minutes and again the rate of synthesis of iodopsin in solution is about the same (Wald, 1961).

The rods can be stimulated by a single quantum of light energy (Hecht, Schlaer and Pirenne, 1942). A quantum of light entering a rod causes rhodopsin to be broken down into retinine and opsin, and this last appears to play a particular role (as yet unknown) in the generation of receptor activity (Wald, 1959). Unfortunately, the transduction process whereby the breakdown of rhodopsin and iodopsin results in the production of a receptor potential and activation of the bipolar cells whose dendrites connect to the rods and cones remains obscure.

The rods and cones are in close opposition to the dendrites of the bipolar nerve cells, which in turn, synapse on ganglion cells whose axons form the optic nerve. In addition the receptors are interconnected by several varieties of association type neurons. The retina is actually a very complex neural system, which, embryologically grows out from the brain rather than being formed peripherally. Although there is only one cell (the bipolar cell) in main line between receptors and galglion cells, various interconnecting association cells give to the system a great complexity.

Thus it can be seen that, whilst similarities do exist between the visual and auditory systems, in terms of both structure and functions, the visual system is very much more complex. Furthermore, the human obtains most information about the external environment through the

visual channel, and as Gibson (1933) has demonstrated, the other senses often modify their responses in accordance with the visual input, so that hearing is still subordinate to vision when seen and heard events conflict (Murch, 1973).

3. Visual Measurements:

A. Visual Threshold: Davson (1962) and Graham (1965) review a variety of tests of scotopic (rod) threshold, measuring a wide range of target angles and sizes and involving numerous approaches with regard to the presence of absence of artificial pupils and lens controlled pathways, as well as differences in binocular versus monocular viewing and the duration of the test flash. A wide range of choice as to the type of threshold measurement one might employ is thus available.

Problems arise, however, in finding a test comparable to that used for the determination of auditory threshold, employing the simple method of limits, and this helps to underline the fundamental difference between the two modalities. As has already been stated, the eyes take a considerable time to dark adapt (approximately 30 minutes), and the presentation of any light stimulus during that period will arrest the process. Furthermore, no readily accessible standardised apparatus comparable to the audiometer is available (people who have deficient vision are tested for the discriminative power of the eye, rather than their performance at visual threshold) to provide a body of normative data.

The apparatus used in this study is an Admiralty Adaptometer, which is used with a standardised technique, and for which norms (at least for Naval personnel) do exist. These will be discussed at greater length at a later stage. The technique also has the advantage that it provides information about what the subject sees in the natural viewing situation - no artificial pupil or refocussing lenses are used, and is comparable in that respect to the hearing test in which no distortion of the auditory apparatus was employed. Responses are recorded across the range of the scotopic threshold curve (or perhaps, more accurately, the mesopic curve) rather than at some point near absolute threshold, thus providing information on individual differences in both the rate and amount of dark adaptation during the specified test period, namely 30 minutes.

B.   Judgement of Intensity - Glare: As with absolute threshold, there
is no exact parallel between the modalities in common use to assess
'comfortable' levels of intensity.   Since we usually respond to light
which is reflected by objects in the immediate environment rather than
to direct light stimulation, measurements of visual discomfort are
usually related to glare (Hopkinson, 1963), and this approach has been
adopted in this thesis.

The rationale and methodology for this approach are similar to
those outlined for the auditory system.   Stevens (1961) has investigated
the slope of brightness function in numerous tests involving the typical
scaling techniques, and has found, at least in the middle of the range,
a constant exponent of 0.33 in the dark adapted eye (for hearing, the
constant exponent is approximately 0.6).   This illustrates that
intensity is perceived in a very similar fashion in both modalities, and
as for the ear, large individual differences have been found (Stevens
and Marks, 1972).

C   Visual Discrimination - Acuity: A large body of normative data
exists for visual acuity showing differences for age, sex and race
(Burg & Hulbert, 1961; Roberts, 1964; McGuinness, 1975).   Because it
is the discriminative power of the eye which is tested in people with
suspected deficient vision, in a practical sense, such tests are
analogous to auditory threshold tests, and provide a means of comparison
between the sample used in this study and a comprehensive range of data.

Visual acuity refers to the ability or capacity of the observer to
perceive fine detail, and researchers commonly employ four types of task
in the assessment of acuity - tests for recognition, resolution,
detection and localisation.   For most people the recognition type of
test is the most familiar, in the form of the Snellen Letter Test, in
which each letter is constructed so that the thickness of the line
segments is equal to one-fifth of the height of the letter.   Unfortunately
the discriminability of all the letters of the alphabet is not the same -
some are easily confused, whilst others are easily recognised.

Rubin and Walls (1969) have pointed out that very few letters on
the Snellen chart constitute a test of resolution acuity.   Such a chart
would consist rather of all B's and E's, F's and P's, or O's and C's.
A more accurate test of resolution is typified by the Landolt Ring, in

which subjects must detect the presence or absence of a small gap in the ring's circle. However, Rubin and Wallis further maintain that resolution acuity is not a fair index of all-round seeing ability, and that the Snellen test is nearer to this than any other test. They therefore recommend that the Snellen test should be retained but used in conjunction with other tests.

For these reasons the Snellen test has been used in this study in conjunction with the Landolt Ring test, which contains a series of rotated broken rings, and is, as stated earlier, a better test of resolution acuity as opposed to recognition acuity. The data from each test are then combined to achieve a more comprehensive measure of each subject.

METHOD: FIRST PHASE EXPERIMENTS

Having discussed the rationale behind the selection of the various measurements employed in the experiments, and decided which tests and techniques should be employed to provide a reasonably comprehensive investigation of sensory sensitivity within and across the auditory and visual modalities, it is now necessary to outline and describe the apparatus and the exact procedures used. Before doing so, however, a description of the subjects used is given.

SUBJECTS

The subjects participating in these experiments were 50 males and 50 females, all of whom were specialist Physical Education students at Nonington College of Physical Education. All were volunteers, and the age range was restricted to young adults of 18 - 25 years. The use of such a group ensures a high degree of similarity to interest, intelligence level, present environment, educational background and bodily training, all of which may have some influence on the results obtained.

In an attempt to isolate the effect of sex differences upon performance, other extraneous variables had to be controlled. The precise details of these controls are discussed in conjunction with the experiments themselves, but they also included the administration of the Eysenck Personality Inventory (Eysenck and Eysenck, 1964), and a simple questionnaire. The former was administered because the personality factors of extraversion, anxiety and neuroticism are believed to relate

to the reaction of the individual to certain aspects of stimulation. Nebylitsyn and Gray (1972) provide a review of some of the findings concerning this problem. The questionnaire sought to provide information concerning:

a. Musical training - the strong effect of musical training on pitch discrimination has already been discussed (Shuter, (1968).

b. Handedness - since certain theories (Milner and Teuber, 1968; Buffery and Gray, 1972) suggest that cerebral dominance is involved in auditory and visual processing, it was considered useful to compare handedness with certain measures of performance.

c. The menstrual cycle - recently it has been proposed that progesterone variation has some influence on perceptual differences between the sexes, with a decrease in progesterone in the premenstrum phase bringing about a slowing in certain central processing systems (Keppell et al, 1969). Female subjects were therefore questioned as to whether or not they were taking a contraceptive pill, and on which day of the menstrual cycle the test was performed.

d. Known auditory or visual defects - subjects were questioned on any history of hearing abnormalities, and the degree of myopia or hyperopia if the subject wore spectacles or contact lenses. Note was also taken of the subject's eye colour, in an attempt to determine whether this had any effect on visual sensory sensitivity.

All testing (Visual and auditory) was carried out by the same experimenter, and both sets of tests were carried out at the same time of day for each subject. Also, females were tested on the same day of their menstrual cycle, when possible.

Plate 1: Audiometer, Testing Room and Booth

Plate 2: Peters' AP6 Clinical Audiometer.
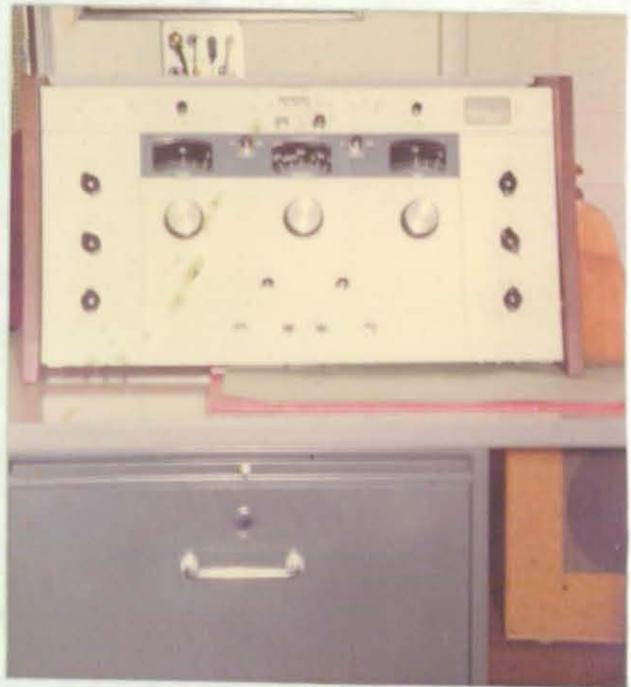
THE AUDITORY EXPERIMENTS

Apparatus: All the auditory experiments were carried out at the
Audiology Department of the Canterbury and District Hospital.   Threshold
and uncomfortable loudness were tested using the same apparatus.   The
subject was seated in a sound-proofed booth, constructed by Amplivox
Hearing Conservation Ltd., with an ambient noise level of 23.5 dBA.   The
booth was situated in an acoustically tiled room, and the ambient noise
level conformed to the recommendation of the MRC Electro-Acoustics
Committee (see Hinchcliffe and Littler, 1958).   The stimulus was
presented via TDH-39 headphones with MX-41/AR cushions by a Peters' AP
6 clinical audiometer (Plates 1 & 2).   The audiometer was checked for
calibration using a Bruel and Kjaer 6 cc coupler (Type 9-A) artificial
ear fitted with a microphone (Type 4144), attached to a Precision Sound
Level meter (Type 2203) and octave filter set (Type 1613), prior to and
on completion of each experimental period.   Calibration was found to be
satisfactory for all these tests, and the calibration figures for
frequencies from 125 Hz to 8,000 Hz are given in Table A.   The calibration
figures available for the AP 6, based on the ISO standardisation data,
allowed the higher frequencies of 10,000 Hz and 12,000 Hz to be checked
only for relative accuracy.   All this apparatus conformed to the
specifications recommended by Hinchcliffe and Littler (1958).

The pitch discrimination test was administered in the same room using
a Linstead LF Signal Generator (Type G2) wired into a key switch and
then into an 8 ohm loudspeaker.   This circuit successfully eliminated any
clicks or variations in the signal.

TABLE 1: Calibration Figures for Frequencies from 125 Hz to 12,000 Hz for the Peters' AP6 Clinical Audiometer used in these Experiments.

1. dB Level at 60 dB above Audiometric Zero

	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000	10,000	12,000
Right	85.7	74.2	70.1	65.2	67.5	69.6	70.6	70.9	73.1	74.0	83.6
Left	86.5	74.5	70.5	65.5	67.4	69.2	70.6	71.2	73.2	74.7	84.7

2. Frequency

	125	260	523	1,040	2,073	3,076	4,065	6.044	8,040	9.971	12,071
Actual Reading	125	260	523	1,040	2,073	3,076	4,065	6.044	8,040	9.971	12,071

Procedure:

1. Threshold: The method adopted here was that outlined by Hinchcliffe
and Littler (1958), now generally accepted as a recommended audiometric
technique, but modified slightly so that having found an 'approximate
threshold', successive tones were then presented in 1 dB, steps to give
a more precise measurement of threshold (clinical audiologists use 5 dB
steps).

The subject was seated comfortably in the sound-proof booth whilst
a standardised set of instructions was read informing him that he would
be presented with a number of simple musical tones into each ear
separately, beginning with the right ear, and asking him to depress a
button every time he heard, or thought he heard, the sound, and to keep
it depressed until the sound disappeared. The button illuminated a light
on the audiometer which could be seen by the experimenter. The subject
was then asked to place the headphones on his head so that they were
comfortable and positioned correctly over the ears. An audible tone
was then presented so that the headphones could be readjusted to ensure
maximum volume and that the headphones were correctly placed with no hair
underneath. The subject could see the experimenter through a glass
panel in the booth, but the experimenter's movements were screened from
him by the audiometer.

A tone lasting about 2 seconds was then presented to the right ear
at 30 dB above audiometric zero for 1,000 Hz, this being recommended as
the starting frequency because Witting and Hughson (1940) found that the
smallest percentage of errors on repeated testing occurred at this frequency.
If this was heard, successive tones each 5 dB lower than the preceding
one were presented until the signal was no longer heard, giving an
approximate threshold. This intensity was then presented on at least
one more occasion, to ensure a two-out-of-four response. The intensity
was then decreased in 1 dB steps with up to four presentations of the
test tone (according to the number required for the two-out-of-four
response criterion) at each intensity. In this way the 'descending
threshold' was determined.

When the tone was no longer heard on four consecutive presentations
at the particular intensity, the intensity was increased in 1 dB steps
until the subject again responded to two out of the four test tones.
This was the 'ascending threshold'. In the majority of cases these

two thresholds are identical, but if they differed the mean of these two readings was taken as the threshold at that particular frequency.

This procedure was then repeated and threshold determined for frequencies of 2,000, 3,000, 4,000, 6,000, 8,000, 10,000, 12,000, 500, 250, and 125 Hz. Threshold for the left ear was then determined in the same way.

2. Uncomfortable Loudness: After threshold had been determined the subject was asked to remove the headphones whilst the second test was explained to him. Again he was informed about the nature of the test, being told that he would be presented with a series of tones which would gradually increase in intensity. He was asked to depress the button when the sound reached a dB level which he felt was 'too loud' on a verbal rating scale which was given as follows: inaudible, faintly audible, distinct, fairly loud, too loud, uncomfortably loud, painful. It was stressed that the experimenter required a purely subjective estimate of the stimulus and in no way was it to be treated as a test of tolerance.

Again the frequency level was set at 1,000 Hz and the attenuation level at 30 dB. The intensity level was then increased in 5 dB steps until the subject depressed the button, to give an approximate level. The intensity was then decreased to 5 dB lower than the approximate level and increased in 1 dB steps until the subject again depressed the button. This procedure was repeated twice more to give three readings for this frequency. The mean of these three readings (to the nearest dB) was then taken as the 'uncomfortable loudness' level for that frequency. Each subject had three trials at all the frequencies in the range 250 - 8,000 Hz in random order (the AP 6 has blocks on the attenuation of levels above and below these frequencies, which made it impossible to test for 'uncomfortable loudness' levels at these frequencies). All tones were presented monaurally to the ear with the best overall threshold or, where this could not be determined, to the right ear.

3. Pitch Discrimination: The subject was seated with the loudspeaker next to either the ear with the best overall threshold or the right ear, as outlined above, and with his back to the signal generator and the experimenter. The subject was told that he would be presented with a reference tone and then after a brief interval with another tone, and was asked to indicate whether the second tone was the same, higher, or lower than the first tone. Intensity was constant at 60 dB, and the

two tones were presented for one second separated by a one second
silence (echoic memory, according to Neisser (1967) lasts for approximately
two seconds). The standards were 500 Hz and 1,000 Hz and there were
eight different comparison tones to each standard at differences of 1%,
2%, 4% and 8% in both directions to the standard.

TABLE 2:   below, gives the exact values in Hz.

Standard		Same	1%	2%	4%	8%
500	Hz	500: 500	495: 505	490: 510	480: 520	460: 540
1,000	Hz	1000: 1000	990: 1010	980: 1020	960: 1040	920: 1080

Each Hz value was included twice in each presentation using a random
sequence, giving a total of 8 'lower' and 8 'higher' and 4 'same'
judgements for each standard and a possible total error score of 40.

THE VISUAL EXPERIMENTS

Apparatus: The visual experiments were carried out in a windowless
room, completely sealed from all external light sources, in the laboratories
of Nonington College of Physical Education.   There was a constant light
level of 5,100 cd/m^2 at source over each day of testing.   Visual acuity
was measured using both the Snellen Letter Test and the Landolt Ring
Test, which were constantly illuminated by an incandescent flood light
of 150 W producing a photometric reading at source of 100,000 cd/m^2,
and a photometric reading on the test card of 9,600 cd/m^2.

Threshold was measured using an A.R.L. Adaptometer, Mark 111.   The
instrument is shown in Plate 3 and Diagrams 1 & 2 and consists of a
rectangular box with a lamp at one end and a circular diffusing glass
viewing screen at the other.   The brightness of this screen can be
varied by the insertion of one or other of a series of 16 graded
apertures at a point about half way between the lamp and the screen.
Screen brightnesses are expressed by the number of the aperture in use
and decrease as these numbers (which are illuminated by a red light).
Consecutive brightnesses differ by about 25%.   Immediately in front of
the screen is a metal plate cut into the form of a sector, which can be
rotated into eight separate positions, and provides a dark shape on the
screen, the position of which the subject is asked to identify.   The
terminals at the back of the adaptometer were connected to a 'Service'

Variable Combined AC & DC Power Supply Unit set to give a 6 volt
output, and the variable resistance on the adaptometer adjusted until the
ammeter needle was positioned precisely under the index mark as seen
through the inspection window.

The apparatus used for the measurement of glare was designed by
Mr. P.T. Stone of Loughborough University of Technology and modified by
the author.   It consists of a wooden box divided into two compartments,
which can be seen through a viewing aperture (see Plate 4 and Diagram 3.
The outer compartment is painted matt black, and during these experiments
was constantly at a luminance level of 10 cd/m^2.   At the rear of the
compartment is a small opaque glass screen and below it a fixation point,
so that the screen is at an angle of 20° to the line of vision.   The
rear compartment is painted white, and contained a variable light source
provided by a 375 watt reflector photoflood photographic lamp, controlled
by a dimmer switch.   This light provided a glare source through the
opaque screen, the intensity of which was measured by a Hagner Universal
Photometer, model S1.

Procedure: Because of the possible problems presented by the processes
of adaptation to different levels of lighting, all subjects performed
the visual tests in the same sequence.   The tests are here described
in the order in which they were presented to the subject.

1.   Visual acuity: After five minutes of adaptation to the room
illumination, the subject was given the tests of visual acuity - the
Snellen Letter Test and the Landolt Ring Test.   Both charts were under
a constant luminance of 100,000 cd/m^2, during the test period.   The
subject was placed 6 metres from the chart, and then asked to identify
the letters on the Snellen Letter Chart and to describe the position of
the break in the ring on the Landolt Test.   Each eye was tested separately,
both with and without spectacles if these were normally worn.

The presentation of the period of adaptation to room lighting and the
standardisation in the presentation of the colour discrimination and
visual acuity tests were undertaken to ensure that all subjects were at
an equal stage of light adaptation before dark adaptation began.

Plate 3: A.R.L. Adaptometer, Mark 111

Plate 4: Glare Box.
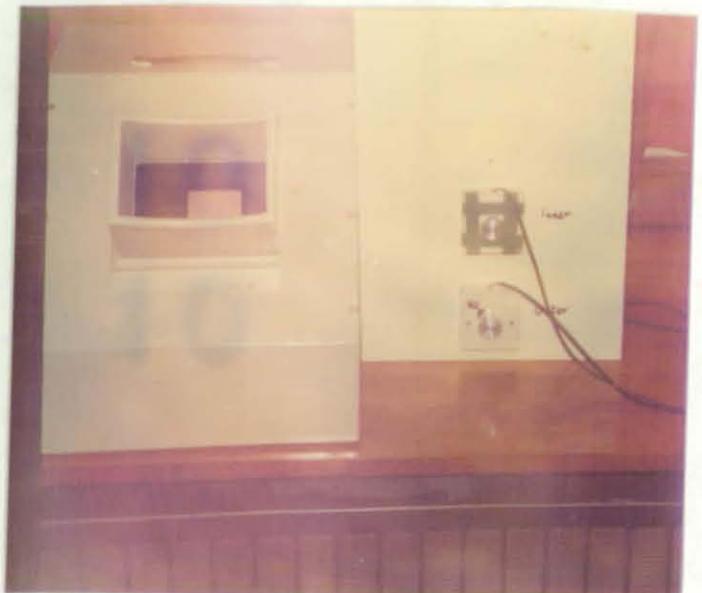
DIAGRAM 1: Admiralty Adaptometer, Mark III - Sectional View.

Spring-loaded catch

Spare calibrated lamps

White diffusing glass

Rotating aperture disc

Rheostat adjustment

Rotating sector

White diffusing glass behind sector viewing screen

Screen to shield observation hole

Locating notch in rotating sector

Pivot for disc

Glass neutral filter

Ammeter

Terminals

Lamp holder mounted on spindle

Cover for Lens

Rheostat

Spring Loaded
Catch

ADAPTOMETER MKIII
ADMIRALTY RESEARCH
LABORATORY No.

6 volts

Rotating aperture
disc

Tube passing illumination
to figure on disc
(stippled red glass under)

Supply
terminals

+6D Lens for Viewing Ammeter
(clear red glass under)

Interior sufaces of this section painted matt black

Viewing visor

DIAGRAM 3: Glare Cabinet.

- 75 -

Removable mounting board

Removable filter

Filter holder

Interior surfaces of this section painted matt white

Exposed surface of source

edge of source

line of sight

Lamps for constant background lighting

Fixation point 90°

Removable opal perspex - 30 grade

Glare source - 375 watt reflector photoflood lamp on separate dimming circuit

2.   Threshold (rate of dark adaptation):   The procedure for using
the A.R.L. Adaptometer is clearly set out in ARL/N2 0358 (Notes and
Instructions on the Use of ARL Adaptometer, Mk.1) and ARL/N6/0358
(Further Instructions supplementing those given in ARL/N2/0358, to
examiners carrying out tests on the Admiralty Adaptometer).   The
subject was seated squarely in front of the viewing screen at a distance
of 6 feet with his chin on a fixed chin rest to ensure that the subject
could not lean forward.   The test was then explained to the subject,
and he was shown the rotating sector on the screen in different positions,
and instructed how to report these positions in terms of the clock face
(12 o'clock, 1.30, 3 o'clock, 4.30, 6 o'clock etc.)   It was explained
that the subject should make reports progressively throughout the test
period of thirty minutes as soon as he felt he could distinguish the
position of the sector, and that the screen brightness would be
progressively reduced during the test.   The subject was then informed
that dimly silhouetted objects can best be seen in the dark by looking
slightly above or to one side of them, and that since no penalty is
attached to making an incorrect report on the position of the sector,
reports should be made on reasonable suspicion rather than on definite
conviction.   The subject was then asked to identify the position of the
rotating sector in three different positions to ensure that he understood
precisely what he had to do.

On completion of these instructions, the experimenter checked that
the electrical connections were securely made, that the voltage output
reading was correct, and that the variable resistance on the adaptometer
was precisely adjusted.   The lights were then turned out and a stop
clock started, and the test commenced by setting the sector in position.
The subject was then told that the screen was faintly illuminated and
that it might take 5 to 10 minutes before any light was discernible, but
that it would eventually appear as a very faint glow on which the subject
would in time be able to discern the position of the sector.   The subject
was warned that the light never appeared as a distinct circle of light,
and that he should give the position of the sector as soon as possible.
The subject was also reminded not to look directly at the screen or to
concentrate so hard that the eyes became tired.

When the subject indicated that he could see the sector, and identified
the position, the sector was moved to a new position with no indication
being given concerning the accuracy of the answer.   Two consecutive

correct answers was adopted as the criterion for evidence of the sector having been seen, as recommended in the Test Instructions.   On fulfillment of this criterion, the time taken to reach that stage was recorded, and the aperture setting was moved one place.   This procedure continued until the end of the thirty minute period.

Recording took place behind a screen, out of the line of sight of the subject, and to ensure that there was no interference with the dark adaptation process, a torch with the lens covered by a red filter was used as the light source for recording.

On the completion of the thirty minute period, the adaptometer was switched off, and the glare test commenced.

3.   Glare (intensity judgement):   The apparatus was switched on so that the outer compartment only was illuminated.   The subject spent five minutes seated with his head against the visor of the apparatus, so that his eyes adapted to this level of illumination (10 cd/m^2), and during this time it was explained that he was to focus on the cross marked at the back of the front compartment, and that a light would appear in the opal window directly above the cross, which would become progressively brighter. The subject was asked to indicate when the glare source became just uncomfortably bright on a verbal rating scale which was given as follows: indiscernible, just discernible, distinct, fairly bright, uncomfortably bright, painful.   It was again stressed that the experimenter required a purely subjective estimate, and that in no way was the test to be treated as one of tolerance.

When the indication had been given, the brightness of the glare source was measured using the photometer, and the value recorded.   The subject then spent a further five minutes looking into the apparatus while only the front compartment was illuminated (at the original luminance) and the test was repeated.   The whole procedure was then repeated once more so that three separate recordings were obtained. The mean of these three readings was then taken as the 'uncomfortable brightness' level.

STATISTICAL ANALYSIS

In the next three chapters, the results obtained from this study
are presented. Before moving on to a consideration of the findings,
however, a brief outline of the statistical analysis employed is called
for. After much consultation it was decided that what is essentially
the least complicated method of analysis was probably the most appropriate.
In this study it is sought, essentially, to determine whether
statistically significant differences are discernible between the means
obtained for the performance of a sample of males and a sample of females
on auditory and visual tests (and later between the mean scores obtained
in a Differential Aptitude Test. Thus it is sought to establish
whether differences exist for just two samples, having essentially the
same variance, in a number of variables. Moreover, with one exception,
all the tests used yield equal-interval data. For this reason, the
simple parametric t-test is used for each variable investigated, with
the exception of visual acuity. The visual acuity test employed in
this study does not yield equal-interval data, and a non-parametric test,
the Sign Test is used, in which the only underlying assumption is that
the variable under consideration has a continuous distribution.

Similarly, extensive correlational analysis is required at a later
stage. Where equal-interval data has been obtained, the parametric
Pearson's Product-Moment Correlation method has been employed, but where
visual acuity is one of the variables involved, the non-parametric
Spearman rank-order correlation coefficient has been obtained.

It has to be admitted that the resulting analysis appears clumsy
and unsophisticated. Moreover, there is a danger that, when doing a
large number of t-tests, 'significant differences' may arise on occasion
as the result of chance! Nevertheless, the tests used are the strongest
available for their purpose, with each variable being treated as a
separate entity.

CHAPTER 4

THE AUDITORY EXPERIMENTS

INTRODUCTION

In previous chapters, experimental evidence relating to differences in performance between the sexes on auditory tests have been presented. The three parameters investigated in this study - threshold, uncomfortable loudness and pitch discrimination - have yielded some useful information about sex differences in previous studies. Thus it has already been noted that females appear to have lower thresholds for high frequency tones, usually above 3,000 Hz (Corso, 1959; 1965, McGuinness, 1975), that they are more sensitive to loudness differences (Pishkin and Shurley, 1965; Elliott, 1971), and that studies on pitch discrimination generally fail to show any differences in performance between the sexes (Shuter, 1968; Bentley, 1968; McGuinness, 1975). No deviation from these findings is expected in this study, but it is hoped that the subjects in this sample will produce comparable performances to the data collected in earlier studies.

1. Threshold

Best ear performance threshold curves of the mean scores for males and females at all frequencies are presented in Figure 1. The mean scores are given in decibels, referenced to 2×10^{-5} Newtons/m^2, SPL. Reference to the curve relating absolute threshold and frequency presented by Licklider (1951), and to other studies already discussed (Corso, 1959; 1965; McGuinness, 1975) suggest that these curves conform to the typical U-shaped curves obtained for this age group, with differences between the sexes in this sample being relatively small, but the males showing the expected threshold elevation above 3,000 Hz. Statistical analysis of this data, employing a "t" test, was then carried out to determine the significance level of the difference between the means at each frequency (if any), and the results are presented in Table 3.

Examination of Table 3 reveals that whilst no significant differences exist between males and females in the middle range of frequencies from 500 Hz to 2,000 Hz, at the tested frequencies below and above this range, significant differences do exist (except at 8,000 Hz) with females being more sensitive throughout. The significant differences found at 125 Hz and 250 Hz in this study are not reported in previous studies, although

Corso (1959, 1965) did find lower mean threshold values for females at these frequencies, as did McGuinness (1975) who surprisingly applied no statistical analysis to her data below 6,000 Hz. Interestingly Table 25, given later in this chapter, providing data for the left ear, wimilarly shows no significant difference in the performance of males and females at these two frequencies.

The lack of a significant difference at 8,000 Hz in this study is surprising. In all previous studies differences in performance at this frequency between males and females have been reported as statistically significant (p 0.02 in McGuinness's study, for example) so that at this frequency the data obtained is atypical of the normative data. The figures obtained here indicate that even for this sample, where males are unlikely to have experienced excessive environmental noise to a greater degree than the females, there is a slight notch in the performance curve of the males at 4,000 Hz (usually explained by association with trauma), which flattens out at 8,000 Hz, whereas the female curve follows a more regular pattern.

The threshold of individual subjects over the whole frequency range was surprisingly inconsistent, with a number of subjects failing to exhibit a regular U-shaped performance curve, and a cross-frequency range of more than 25 dB being common. This inconsistency is reflected in the correlational data presented in Table 4 (obtained using Pearson's Product-Moment Correlation Coefficient), showing the correlations obtained between threshold intensity at all frequencies for the total sample. As can be seen, correlations are frequently low (particularly between low and high frequencies), and on occasion fail to achieve statistical significance at the 0.05 level. This could indicate that one must consider threshold as a function of frequency rather than over the range of frequencies for any one individual.

TABLE 3: t Tests : Auditory threshold, best ear. Males v. Females

FREQUENCY	GROUP	MEAN (dB.)	S.D.	S.E.M.	t VALUE	SIGNIFICANCE LEVEL
125 Hz	M F	29.10 26.60	4.75 4.86	.67 .69	2.71	.01
250 Hz	M F	17.38 15.08	4.95 3.70	.70 .52	2.63	.02
500 Hz	M F	11.78 10.90	3.35 3.59	.47 .51	1.27	-
1,000Hz	M F	6.50 6.58	3.47 3.65	.49 .52	.11	-
2,000Hz	M F	8.76 8.26	3.66 3.35	.52 .47	.71	-
3,000Hz	M F	13.68 11.60	5.41 4.15	.76 .59	2.16	.05
4,000Hz	M F	16.50 11.78	4.94 3.79	.70 .54	5.36	.001
6,000Hz	M F	17.42 13.96	7.73 4.16	1.09 .59	2.79	.01
8,000Hz	M F	15.56 14.86	7.75 4.53	1.10 .64	.63	-
10,000Hz	M	16.52 12.98	7.62 6.63	1.09 .94	2.48	.02
12,000Hz	F	24.10 20.58	8.77 8.54	1.24 1.21	2.03	.05

FIGURE 1 : Auditory threshold curves for males and females. Best ear.
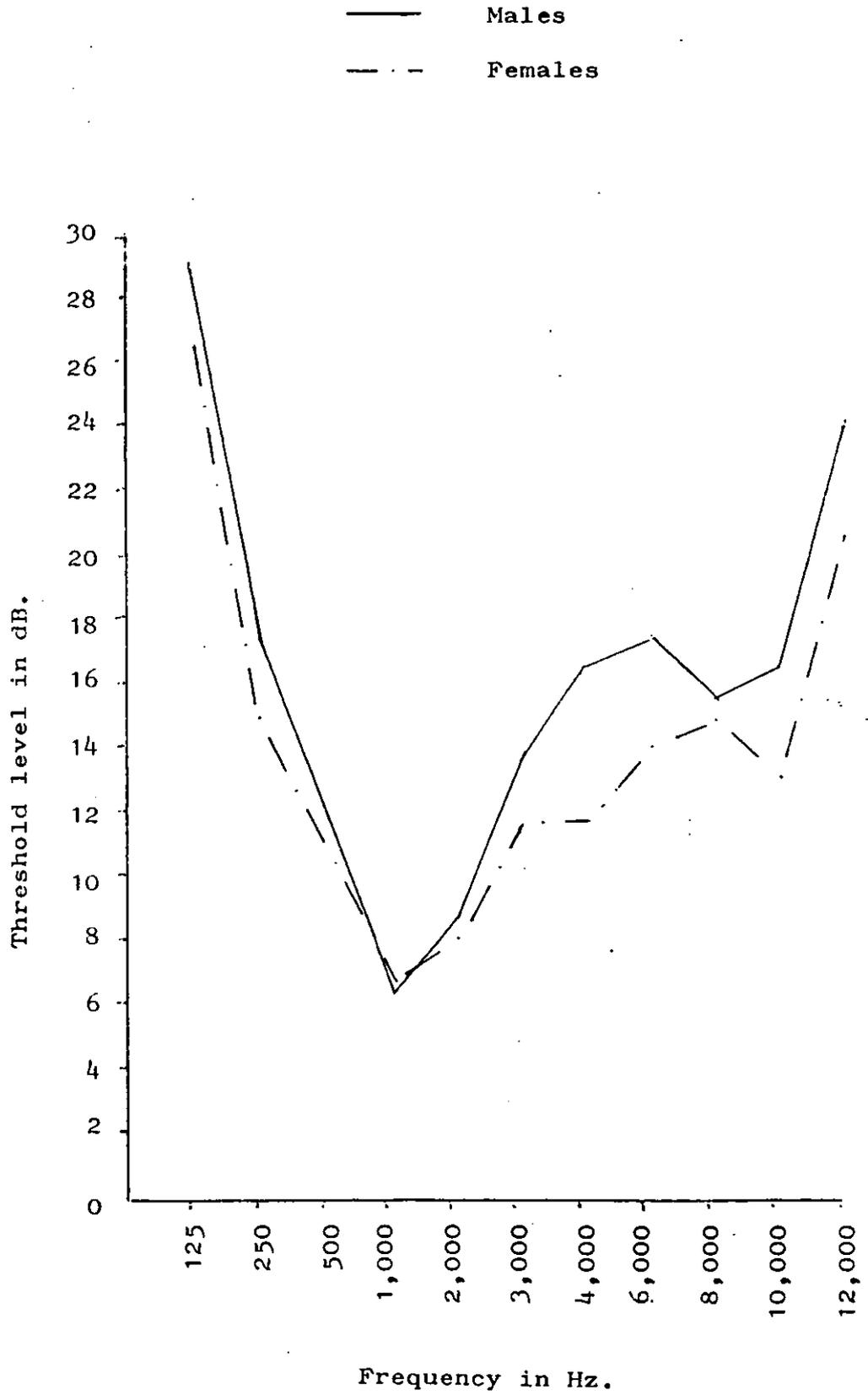
TABLE 4,   AUDITORY THRESHOLD BETWEEN FREQUENCY CORRELATIONS

For Total Sample (Best Ear).

FREQUENCY	250	500	1,000	2,000	3,000	4,000	6,000	8,000	10,000	12,000
125	,80	.52	.19	.15	.35	.43	.42	.25	.08	.11
250		:68	.30	.20	.33	.37	.35	.15	.15	.06
500			,49	.37	.33	.25	.29	.29	.17	.26
1,000				.53	.24	.20	.14	.24	.25	.32
2,000					.43	.41	.32	.41	.25	.32
3,000						.64	.50	.38	.24	.17
4,000							.76	.36	.31	.41
6,000								.51	.34	.31
8,000									.45	.36
10,000										.65

Value of r at 0.05 significance level = .20 (98 df); .14 (198 df)

Value of r at 0.01 significance level = .26 (98 df); .19 (198 df)

2. Uncomfortable Loudness

The mean scores for both males and females in the uncomfortable loudness test at all frequencies from 250 Hz to 8,000 Hz are presented in Table 5, together with the standard deviation, standard error of the mean, and results of the statistical analysis (again utilising the 't' test at each frequency). As can be seen, the difference is virtually constant at between approximately 8 and 0 dB for all the frequencies tested, a statistically significant difference for each frequency. The curves of the mean scores for this test are presented in Figure 2.

Despite the relatively subjective nature of this test, individual subjects were remarkably consistent in their estimations of 'just uncomfortable' loudness, seldom varying by more than 5 dB for any frequency over each of their three trials. Relative consistency was also shown across the frequency range, and this consistency is reflected in the Pearson's Product-Moment Correlation Coefficients obtained between the frequencies, presented in Table 6. In this instance correlations are high, and all are significant at at least the 0.01 level.

The results obtained for this test correspond with other research findings. The investigation by Elliott (1971) on a sample of children aged 7 - 12 years, using white noise as a stimulus,concluded that females were significantly more sensitive than males across all ages. McGuinness (1975), using a method similar to that described in this study, also reported that young adult females were significantly more sensitive to loudness than males with a mean difference between the sexes over all frequencies of 7.8 dB (compared to 8.63 dB in this sample) and a mean loudness level over all frequencies of 83.3 dB for men and 75.5 dB for women (91.25 dB and 82.62 dB respectively in this sample). The slightly higher values obtained in this study are probably due to the difference in methodology between the two studies, reported in Chapter 3.

TABLE 5: Uncomfortable Loudness Judgement – Males v Females

FREQUENCY	GROUP	MEAN (dB.)	S.D.	S.E.M.	t VALUE	SIGNIFICANCE LEVEL
250 Hz	M F	91.40 82.14	11.77 13.42	1.66 1.90	3.63	.001
500 Hz	M F	90.50 82.54	11.31 12.19	1.60 1.72	3.35	.01
1,000Hz	M F	90.58 81.64	9.84 10.32	1.39 1.46	4.39	.001
2.000Hz	M F	91.90 82.72	10.87 10.57	1.54 1.50	4.24	.001
3,000Hz	M F	93.04 84.56	12.29 12.00	1.74 1.70	3.46	.001
4,000Hz	M F	93.66 84.44	13.33 13.62	1.89 1.93	3.39	.01
6,000Hz	M F	92.58 83.18	14.20 15.31	2.01 2.17	3.15	.01
8,000Hz	M F	86.34 79.76	14.15 16.22	2.00 2.29	2.14	.05

Table 6: Uncomfortable Loudness: Between Frequency Correlations
Total Sample

FREQUENCY	500	1,000	2,000	3,000	4,000	6,000	8,000
250	.89	.80	.84	.84	.85	.85	.81
500		.85	.86	.87	.85	.86	.80
1,000			.87	.85	.84	.78	.69
2,000				.94	.88	.86	.78
3,000					.90	.87	.82
4,000						.90	.85
6,000							.85

FIGURE 2 : Uncomfortable
Loudness Judgement curves for males
and females.

- 88 -
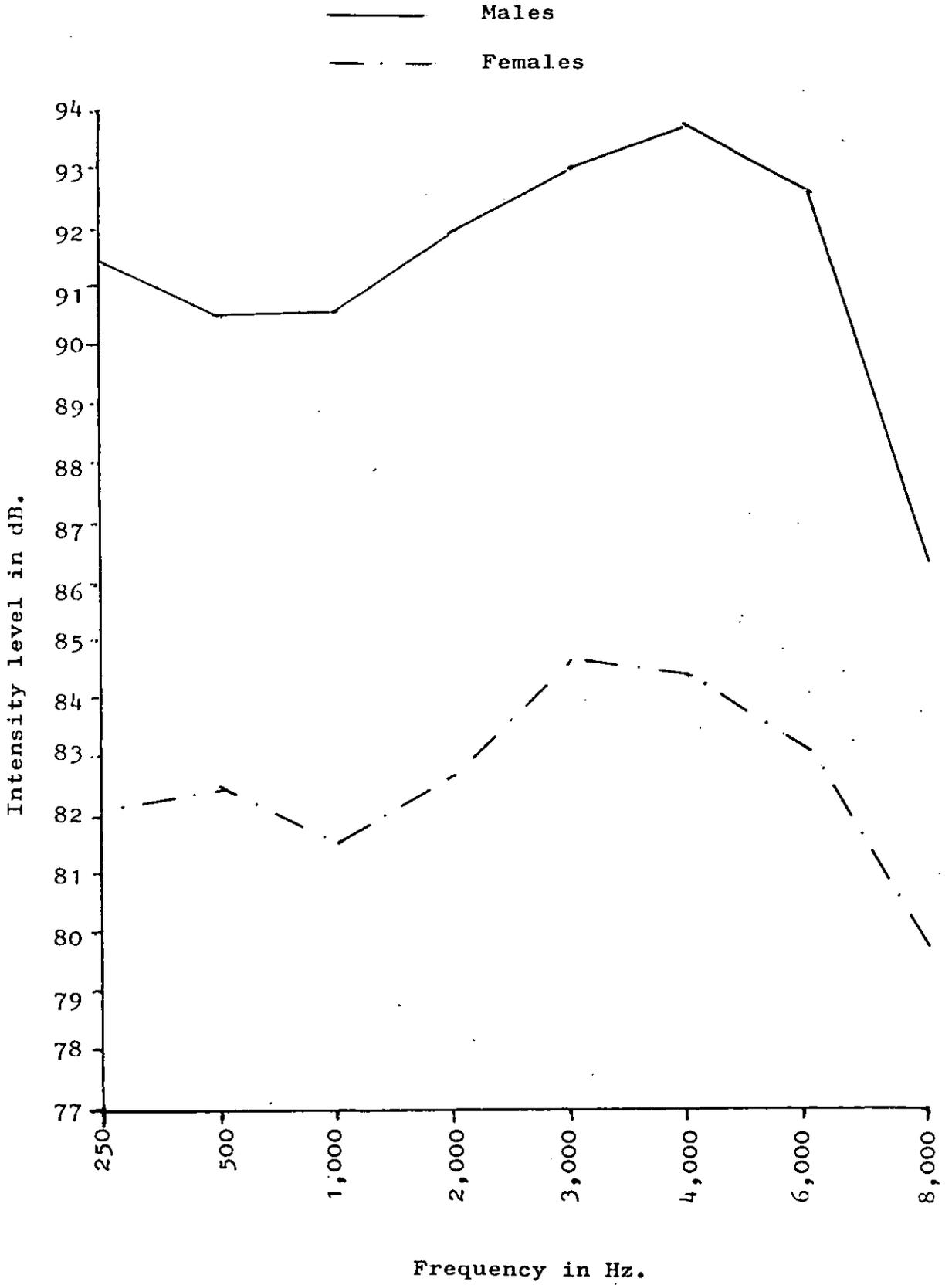
3. Pitch Discrimination

As stated earlier no significant differences in performance
between the sexes have been shown in previous studies of pitch
discrimination.   A histogram of the error scores for both males
and females is presented in Figure 3, showing that more females
than males scored less than 7 errors.   However, when a t test was
applied to the data no significant difference between the mean
scores was apparent.   The mean error score, standard deviation and
standard error of the mean for both males and females are presented
in Table 7, together with the results of the statistical analysis.

TABLE **7.** Pitch Discrimination: Men v Women

	MEAN ERRORS	S.D.	S.E.M.	t VALUE	SIGNIFICANCE LEVEL
Men	7.46	3.90	.55	1.067	-
Women	6.60	4.08	.58		

Shuter (1968) and McGuinness (1975) both provide evidence that
musical training enhances performance in pitch discrimination tests,
and one would consequently expect to find a significant correlation
between discriminative ability and musical training.   When the Pearson
Product-Moment formula was applied to the data, significant negative
correlations were found between the error score and the number of years
spent in musical training as follows:

Men - 0.52 (p > .01):   Women - 0.45 (p > .01);

Total Sample - 0.48 (p > .01).

Interestingly there was a significant difference between the males and
females in the mean number of years spent in musical training (p > .001)
in favour of the females, with a greater number of females having received
musical training (N=22, compared to N=12 for the males).   This
information is summarised in Table 8, and would go some way towards
explaining the differences observed in Figure 3.   It should be noted,
however, that a few subjects with no formal musical background had
excellent scores in this test.

FIGURE 3 :   Pitch Discrimination Error Scores
             for males and females.
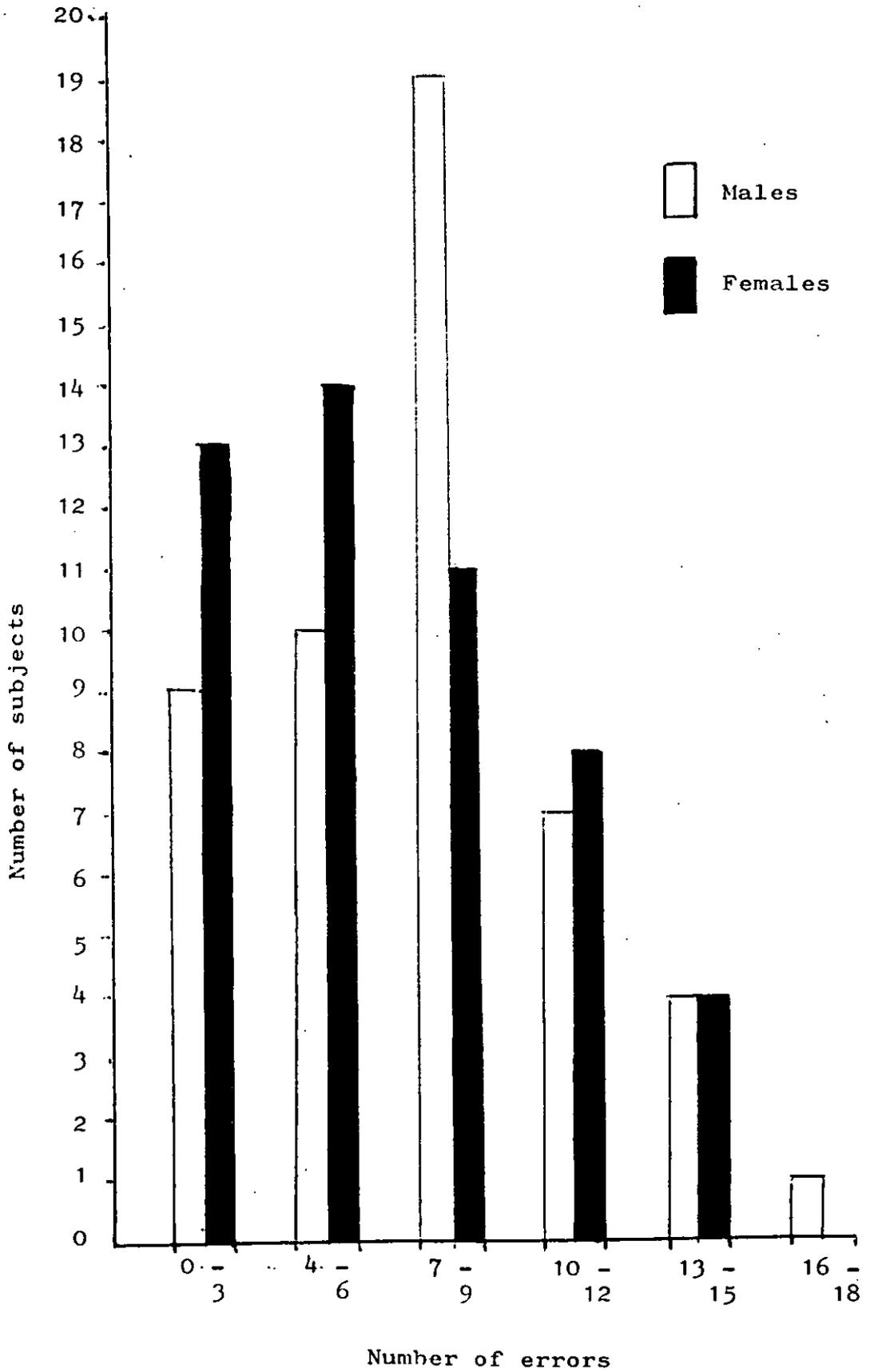
TABLE 8.   Musical Training: Men v Women

MEAN (YRS.)		S.D.	S.E.M.	t VALUE	SIGNIFICANCE LEVEL
Men	1.19	1.42	.20	3.78	.001
Women	2.42	1.82	.26		

Intra - Modality Correlations

In an attempt to ascertain whether or not sensory performance in one auditory test bears any relationship to performance in other auditory tests, Pearson's Product-Moment Correlation Coefficients were computed to determine both the degree and the significance of the relationship between tests.

1.   Threshold and loudness.   The correlations between threshold and 'just comfortable' loudness at all frequencies are presented in Table 9 for males, females and the total sample.   No consistent relationship is apparent, although some results are statistically significant.   In view of the inconsistency of the threshold correlations and relative consistency of the loudness correlations reported earlier (Tables 4 and 6), this was expected.   The correlations were low across all frequencies, with some negative results, and it would appear that having a high or low auditory threshold is of relatively little predictive value in determining the subjective reactions to levels of intensity.   Loudness would appear to be more a function of some higher level capacity of tolerance rather than of threshold.

TABLE 9   Correlations between auditory threshold and uncomfortable loudness.

	250 Hz	500 Hz	1,000 Hz	2,000 Hz	3,000 Hz	4,000 Hz	6,000 Hz	8,000 Hz
Men	-.02	.05	-.01	.20*	.22*	.02	.08	.19
Women	.31+	.26+	.09	-.01	.22*	.21*	.30+	.09
Total	.21+	.19+	.04	.12	.28+	.24+	.22+	.15+

* significant at 0.05 level   + significant at 0.01 level

2.   Threshold and Pitch Discrimination.   The standard tones used
in the pitch discrimination test were 500 Hz and 1,000 Hz.   Table
10 shows the correlations obtained between the auditory threshold
levels at these frequencies and the number of errors on the pitch
discrimination test.   Again correlations are low and suggest that
sensitivity at threshold bears little relationship to the determination
of 'just noticeable differences' in pitch.

TABLE 10.   Correlations between auditory threshold and pitch.

	500 Hz	1,000 Hz
Men	.21*	.07
Women	.15	.24*
Total	.19*	.16*

* significant at 0.05 level

3.   Loudness and Pitch Discrimination.   The error scores on the
pitch discrimination test were correlated with the uncomfortable
loudness scores at 500 Hz and 1,000 Hz with the results shown in
Table 11.   None of these results is significant.

TABLE 11.   Correlations between loudness and pitch

	500 Hz	1,000 Hz
Men	.15	.13
Women	.09	.11
Total	.13	.13

The Menstrual Cycle

Evidence has been presented by Semszuk et al (1967) and Baker and Weiler (1977) that auditory sensitivity is influenced by the menstrual cycle, with the greater sensitivity occurring just prior to ovulation (presumably as a result of hormonal changes). Baker and Weiler further report that females who are taking combination birth control pills have lower auditory thresholds than normally cycling females and males. In pitch discrimination Wynn (1971) indicates the existence of a bimensual cycle, with lower frequency estimates at around both ovulation and menstruation. In an attempt to relate the present data to these studies the female sample was divided into three sub-groups:- A: those taking a contraceptive pill (N=12), B: those in the pre-ovulation phase of the cycle on the day of testing, and C: those in the post-ovulation phase of the cycle on the day of testing.

1. Auditory threshold: Table 12 shows the mean values obtained for each of the three groups, together with their standard deviation and standard error of the mean at each of the frequencies tested. No significant differences between these means were revealed by statistical analysis (t test) but it is interesting to note that at most frequencies the value obtained for the pre-ovulation group is lower. This is consistent with the findings of Baker and Weiler, who noted that in their group of normally cycling females a significantly lower threshold was obtained during their pre-ovulation phase than during their post-ovulation phase, (no attempt was made in this study to test the females at regular intervals over their menstrual cycle). No support could be found, however, for their assertion that females taking a contraceptive pill had a lower auditory threshold than other females. Figure 4 shows in histogram form, the mean values obtained for each of the three female groups, and the males.

Comparison of each of the three groups with the males in performance at auditory threshold, at each frequency, provides some interesting, if inconsistent, information. Table 13 shows the results of statistical analysis, using the 't' test, of this comparison. Although at all frequencies the three groups display lower mean threshold values than the males, greater significant differences are obtained between the pre-ovulation group and the males, than are obtained for the other two groups. Greater consistency of results would lead one to accept this as conclusive evidence that cyclical hormonal fluctuations are responsible for differences between the sexes in auditory threshold.
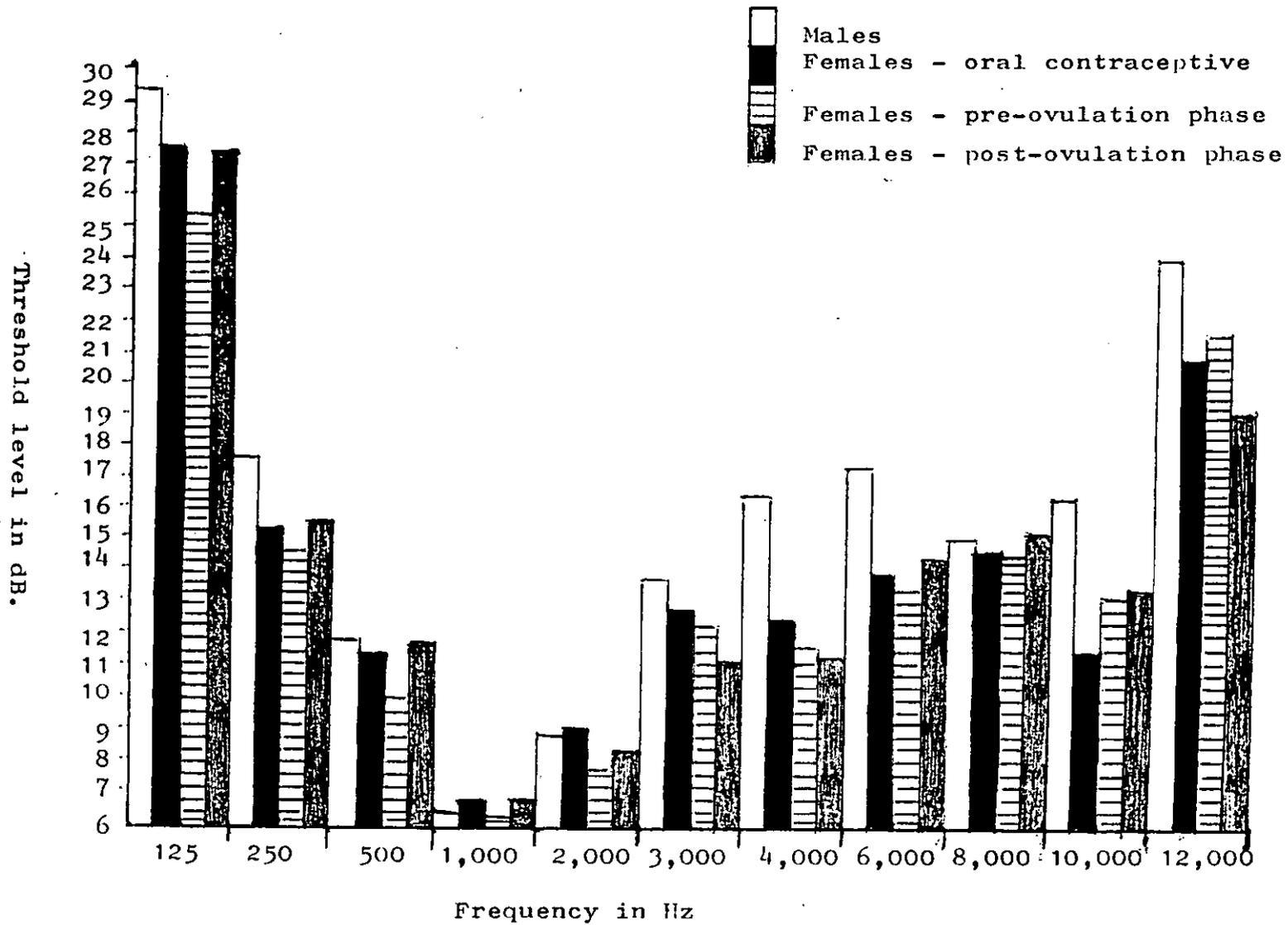
FIGURE 4 : Histogram of mean threshold values obtained for males, and the three female sub-groups.

- 94 -

TABLE 12: Auditory Threshold: Mean. Standard Deviation and
Standard Error of the Mean for Female Sub Group (in dBs)

FREQUENCY	GROUP	MEAN	S.D.	S.E.M.	FREQUENCY	GROUP	MEAN	S.D.	S.E.M
125	A	27.61	4.74	1.43	4,000	A	12.60	4.38	1.32
	B	25.23	4.20	.96		B	11.60	4.16	.95
	C	27.35	5.42	1.21		C	11.45	3.17	.71
250	A	15.29	3.48	1.05	6,000	A	14.08	4.19	1.26
	B	14.57	3.52	.81		B	13.58	3.33	.77
	C	15.45	4.10	.92		C	14.25	4.96	1.11
500	A	11.28	3.74	1.13	8,000	A	13.92	3.09	.93
	B	9.99	2.49	.57		B	14.84	5.61	1.29
	C	11.55	4.31	.96		C	15.40	4.16	.93
1,000	A	6.75	4.18	1.26	10,000	A	11.73	3.52	1.06
	B	6.20	3.92	.90		B	13.16	5.96	1.37
	C	6.85	3.23	.72		C	13.50	8.50	1.90
2,000	A	8.96	3.36	1.01	12,000	A	20.96	10.56	3.18
	B	7.87	3.40	.73		B	21.84	9.69	2.22
	C	8.25	3.42	.76		C	19.25	6.05	1.35
3.000	A	12.78	2.14	.64					
	B	12.44	4.93	1.13					
	C	11.15	4.21	.94					

TABLE 13: t Tests for Auditory Threshold: Males v Three Female Sub Groups.

FREQUENCY	FEMALE GROUP	t VALUE	SIGNIFICANCE	FREQUENCY	FEMALE GROUP	t VALUE	SIGNIFICANCE
125	A B C	.94 3.12 1.34	– .01 –	4,000	A B C	2.42 3.80 4.24	.02 .001 .001
250	A B C	1.33 2.27 1.54	– .02 –	6,000	A B C	1.39 2.09 1.70	– .05 –
500	A B C	.44 2.11 .24	– .05 –	8,000	A B C	.73 .42 .14	– – –
1,000	A B C	.20 .31 .39	– – –	10,000	A B C	2.03 1.73 .97	.05 – –
2,000	A B C	.16 .92 .54	– – –	12,000	A B C	1.03 .92 2.31	– – .05
3,000	A B C	.78 1.15 2.17	– – .05				

Men v Group A : 59 df (Pill)

Men v Group B : 67 df (Pre-Ovulation)

Men v Group C : 68 df (Post-Ovulation)

Uncomfortable

TABLE 14: <u>Loudness Judgement</u>: Mean. Standard Deviation and Standard Error of the Mean for Female Sub Groups (in dBs)

FREQUENCY	GROUP	MEAN	S.D.	S.E.M.	FREQUENCY	GROUP	MEAN	S.D.	S.E.M
250	A B C	85.73 79.53 82.65	12.24 13.70 13.89	3.69 3.14 3.11	3,000	A B C	87.00 81.95 85.70	17.37 10.41 9.93	5.24 2.39 2.22
500	A B C	84.64 79.58 84.20	14.15 10.10 12.92	4.27 2.32 2.89	4,000	A B C	87.36 81.16 85.95	16.97 11.02 13.93	5.12 2.53 3.11
1,000	A B C	81.64 78.58 84.55	10.19 9.20 11.01	3.07 2.11 2.46	6,000	A B C	84.55 80.05 85.40	17.35 15.01 14.71	5.23 3.44 3.29
2,000	A B C	84.55 80.74 83.60	13.03 9.79 10.07	3.93 2.25 2.25	8,000	A B C	80.91 78.84 80.00	17.59 17.97 14.43	5.30 4.12 3.23

2. Uncomfortable Loudness: The mean values obtained for each
of the three female sub-groups at each frequency are presented in
Table 14, and the resultant curves can be seen in Figure 5.   Again,
although in all instances the value obtained for the pre-ovulation
group is lower, the 't' test revealed no significant differences
between the three groups at any of the frequencies tested.

In Table 15 these mean values are compared to those of the male
group by means of statistical analysis, again employing the 't' test.
Again the greatest and most significant differences are those obtained
for the pre-ovulation group, whilst the group taking the pill resemble
closely the male group in performance on this test.   Since it has
already been suggested that threshold does not appear to be related
to the level of subjective reaction to intensity, it would seem likely
that some neural mechanism determining loudness tolerance is also
influenced by the hormonal changes accompanying the menstrual cycle.

3. Pitch Discrimination: No significant differences were
obtained between the mean error scores of the three sub-groups in
the pitch discrimination test, which are presented in Table 16.
The 't' test further failed to reveal any significant differences
between the mean scores of each female sub-group and that of the males.
No corroboration of Wynn's (1971) findings could be given, since if
females show a bimensual cycle in pitch discrimination, the division
of this sample of normally cycling females into only two groups, would
mean that one peak would cancel out the other.

TABLE 15: t Tests for Loudness: Males v Three Female Sub-Groups

FREQUENCY	FEMALE GROUP	t VALUE	SIGNIFICANCE	FREQUENCY	FEMALE GROUP	t VALUE	SIGNIFICANCE
250	A B C	1.44 3.57 2.67	- .001 .01	3,000	A B C	1.36 3.49 2.38	- .001 .05
500	A B C	1.48 3.69 2.02	- .001 .05	4,000	A B C	1.35 3.64 2.16	- .001 .05
1,000	A B C	2.71 4.61 2.24	.01 .001 .05	6,000	A B C	1.63 3.22 1.90	- .01 -
2,000	A B C	1.96 3.91 2.95	- .001 .01	8,000	A B C	1.10 1.82 1.68	- - -

Man v Group A : 59 df (Pill)

Man v Group B : 67 df (Pre-Ovulation)

Men v Group C : 68 df (Post-Ovulation)

FIGURE 5 :   Uncomfortable Loudness curves for males and
              three female sub-groups.
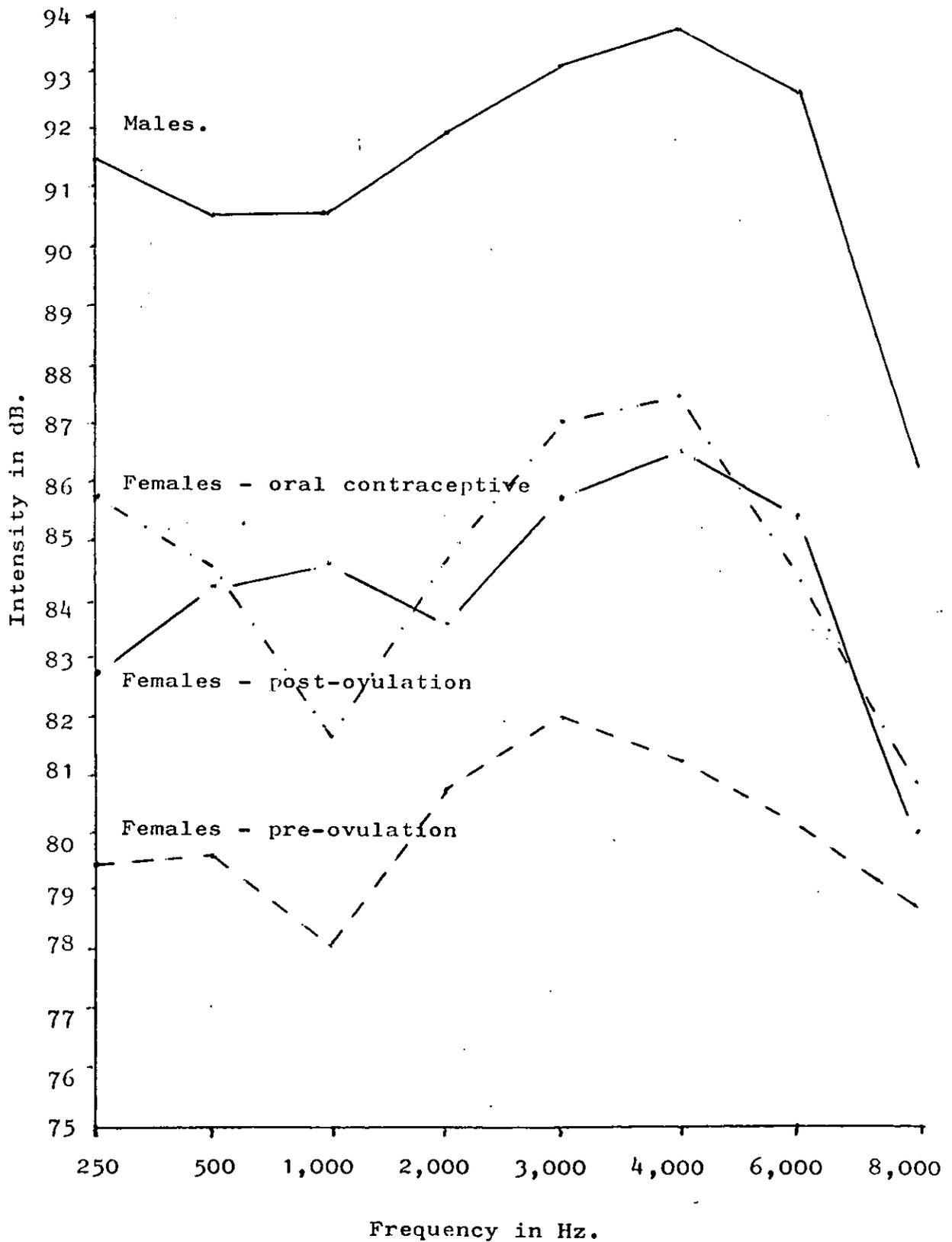
TABLE 16: Pitch Discrimination : Mean Error Score
Standard Deviation and Standard Error of the Mean
for Female Sub-Groups.

GROUP	MEAN	S.D.	S.E.M.
A	6.00	3.87	1.17
B	7.11	4.29	.99
C	6.45	4.12	.92

Personality and the Auditory Modality

Eysenck and Levy (1972) suggest that all sensory thresholds are related to personality, with introverts having the lower thresholds. However they present no experimental evidence to support this suggestion. In fact, where basic sensory or perceptual tasks have been investigated with regard to personality differences, the findings are far from consistent (see Nebylitsyn and Gray 1972), whilst Ippolitov (1972) suggests that when sex differences are isolated, the amount of variance due to sex is significantly greater than that due to personality factors.

Studies relating auditory tasks to personality have produced conflicting results. Elliott (1971) and Smith (1968) found that performance in auditory tasks is related to extraversion, but other studies (Pearson and Hart, 1969; Stephens, 1970; Stephens and Anderson, 1971) report that similar types of judgement are related to anxiety. Where studies have controlled for sex differences (Elliott, 1971; McGuinness, 1975), the relationship of introversion - extroversion to judgement of intensity is consistent only in females. Thus no clear relationship between personality factors and auditory tasks has emerged from the experimental evidence at present in existence. Since, however, these personality factors are believed to relate to the reaction of the individual to certain aspects of a stimulus, the Eysenck Personality Inventory (Eysenck and Eysenck, 1964) was administered to the subjects to act as a monitor of personality effect. Correlations between their scores in both extraversion - introversion and neuroticism - stability and their performance scores in the auditory tests were then computed, using the Pearson Product-Moment Correlation Coefficient.

1. Male and Female Personality Scores: Using the 't' test, no significant differences were found between the males and females either on extroversion or neuroticism mean scores. As might have been expected in a sample of Physical Education students, extraversion scores were, on the whole, high, whilst on the neuroticsm - stability scale, the mean scores lie at about the mid-point of the scale. Table 17 shows the mean scores in both parameters, together with their standard deviation and standard error of the mean, for both the male and female groups.

TABLE 17: Personality Factors: Mean, Standard Deviation and
Standard Error of the Mean for Males and Females.

PARAMETER	GROUP	MEAN	S.D.	S.E.M.
EXTRAVERSION	MALES	16.78	4.37	.62
	FEMALES	15.14	4.05	.57
NEUROTICISM	MALES	9.24	4.53	.64
	FEMALES	10.44	4.08	.58

No significant differences were detected between the three
female sub-groups in either personality parameter, enabling the
female group to be treated as a whole in the correlational data.
Interestingly, however, the sub-group taking the pill obtained a
noticeably higher mean score in extraversion than the other two
sub-groups (see Table 18)

TABLE 18: Personality Factors; Mean, Standard Deviation and
Standard Error of the Mean for Three Female Sub Groups.

PARAMETER	GROUP	MEAN	S.D.	S.E.M.
EXTRAVERSION	A	17.09	3.24	.98
	B	14.89	3.34	.79
	C	14.33	4.75	1.04
NEUROTICISM	A	10.73	3.93	1.18
	B	10.28	3.68	.87
	C	10.43	4.64	1.01

TABLE.19   CORRELATIONS BETWEEN AUDITORY THRESHOLD AND EXTRAVERSION

GROUP	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000	10,000	12,000
MEN	.23*	.26*	.09	.17	.01	.08	.07	.22*	.10	.17	.15
WOMEN	-.05	.15	.11	.03	.17	.14	.07	.04	.01	-.16	.20
TOTAL	.13	.25*	.13	.09	.10	.14	.15	.20	.08	.06	.02

* significant at .05 level.

TABLE 20   CORRELATIONS BETWEEN AUDITORY THRESHOLD AND NEUROTICISM

GROUP	125	250	500	1,000	2,000	3,000	4,000	6,000	8,000	10,000	12,000
MEN	-.11	-.14	-.26*	-.15	.04	.07	.03	.04	.06	-.12	-.15
WOMEN	.16	-.09	-.01	.02	.09	.24*	.15	.14	-.07	-.09	.07
TOTAL	-.02	-.15	-.15	-.07	.05	-.03	-.03	.03	.01	-.14	-.07

* significant at .05 level

2.   Personality and Threshold.   Table 19 shows the correlations
obtained between threshold at each of the frequencies tested and
extraversion.   In all instances correlations are low (sometimes
negative) and seldom achieve significance.   Examination of the
correlations obtained between neuroticism and threshold (Table 20)
shows a remarkably inconsistency, varying from negative to positive
and again rarely achieving significance.   Thus the evidence fails
to support Eynsenck and Levy's (1972) suggestion that a relationship
exists between sensory threshold and personality, at least in the
auditory modality.   However, the subject group used here are rather
homogenous.

3.   Personality and Uncomfortable Loudness.   Correlations between
loudness and extraversion provide a different picture to that obtained
for threshold.   Whilst the male group demonstrates no relationship,
a consistent and significant relationship is obtained for the females
(which then gives rise to a relationship for the whole sample).   These
results confirm the findings of Elliott (1971) and McGuinness (1975).
Table 21 shows the correlations obtained between loudness and extraversion
and Table 22 the correlations for loudness and neuroticism for males,
females and the total sample.   The latter display some inconsistencies,
but most are negative and none are significant.   The data poses some
problems for the plausibility of modern personality theory.

TABLE 21:   Correlations between Uncomfortable Loudness and Extraversion.

GROUP	250	500	1,000	2,000	3,000	4,000	6,000	8,000
MEN	.03	-.01	-.01	-.01	.03	.14	.18	.17
WOMEN	.45*	.30*	.38*	.34*	.33	.36*	.40*	.37*
TOTAL	.29*	.20+	.20+	.22+	.22+	.29*	.33*	.30*

+   significant at .05 level   * significant at .01 level

TABLE 22: Correlations Between Uncomfortable Loudness and Neuroticism

GROUP	250	500	1,000	2,000	3,000	4,000	6,000	8,000
MEN	-.01	.07	-.09	.06	.05	-.07	.16	.06
WOMEN	-.01	-.12	-.12	-.05	-.05	-.03	.02	-.01
TOTAL	-.04	-.07	-.15	-.05	-.04	-.09	.04	-.01

4. Personality and Pitch Discrimination: No significant relationship was obtained between pitch discrimination error scores and either of the two personality factors, as can be seen from Table 23.

TABLE 23 : Correlations Between Pitch Discrimination and Personality Factors

	MALES	FEMALES	TOTAL SAMPLE
EXTRAVERSION	.05	-.09	.01
NEUROTICISM	.04	-.13	-.06

Laterality. Tables 24 and 25 show the mean threshold performance scores of both males and females for the right and left ears respectively, together with the results of statistical analysis between the two groups. The performance curves for each ear are given in Figures 6 and 7. As can be seen the results conform closely to those already given in Table 3, except that for the left ear no significant difference was found between the males and females at 125 Hz and 250 Hz.

Determination of the 'best ear' often proved difficult, since it was common to find one ear superior at some frequencies, and the opposite ear superior at others. Consequently there is an apparent discrepancy at some frequencies, where the mean score obtained for the left ear is actually less than that obtained for the 'best' ear. Within the total group there were more left-eared subjects (both males and females) than right-eared. Table 26 shows the number of subjects in each group with better left or right ear performances.

TABLE 24: t Tests.   Auditory Threshold, Right Ear.   Males v Females

FREQUENCY	GROUP	MEAN (dB)	S.D.	S.E.M.	t Value	SIGNIFICANCE LEVEL
125Hz	M F	32.40 29.78	4.95 5.12	.70 .72	2.58	.02
250Hz	M F	20.38 17.30	4.93 4.56	.70 .65	3.21	.01
500Hz	M F	13.36 12.80	4.06 4.28	.57 .61	.67	-
1,000Hz	M F	7.62 8.14	3.76 3.64	.53 .52	.70	-
2,000Hz	M F	9.50 8.96	4.55 4.16	.64 .59	.61	-
3,000Hz	M F	14.78 13.92	4.54 4.29	.64 .61	.96	-
4,000Hz	M F	17.44 13.36	6.48 4.24	.92 .60	3.69	.001
6,000Hz	M F	17.94 13.56	8.18 4.22	1.16 .60	3.33	.01
8,000Hz	M F	16.74 16.94	8.26 6.73	1.17 .81	.14	-
10,000Hz	M F	19.16 14.62	9.84 8.08	1.39 1.14	2.50	.02
12,000Hz	M F	28.80 21.98	11.17 8.63	1.58 1.22	2.94	.01

TABLE 25: t Tests. Auditory Threshold, Left Ear. Males v
Females

FREQUENCY	GROUP	MEAN (dB)	S.D.	S.E.M.	t VALUE	SIGNIFICANCE LEVEL
125Hz	M F	28.83 27.80	5.10 5.25	.72 .74	.99	-
250Hz	M F	16.48 15.74	4.76 4.25	.67 .60	.81	-
500Hz	M F	12.30 11.76	3.16 3.80	.45 .54	.77	-
1,000Hz	M F	6.86 6.76	3.59 3.62	.51 .51	.14	--
2,000Hz	M F	8.54 8.56	3.56 3.06	.50 .43	.03	--
3,000Hz	M F	14.46 11.28	6.33 3.90	.90 .55	3.00	.01
4,000Hz	M F	16.32 12.06	5.62 4.05	.80 .57	4.31	.001
6,000Hz	M F	18.26 14.10	8.11 5.66	1.15 .80	2.94	.01
8,000Hz	M F	17.14 15.00	8.04 4.95	1.13 .70	1.59	-
10,000Hz	M F	19.38 14.30	9.29 6.77	1.31 .96	3.10	.01
12.000Hz	M F	26.64 22.06	9.24 8.21	1.31 1.16	2.60	.02

FIGURE 6 : Auditory threshold performance curves
for males and females - right ear.

FIGURE 7 : Auditory threshold performance curves
for males and females - left ear.
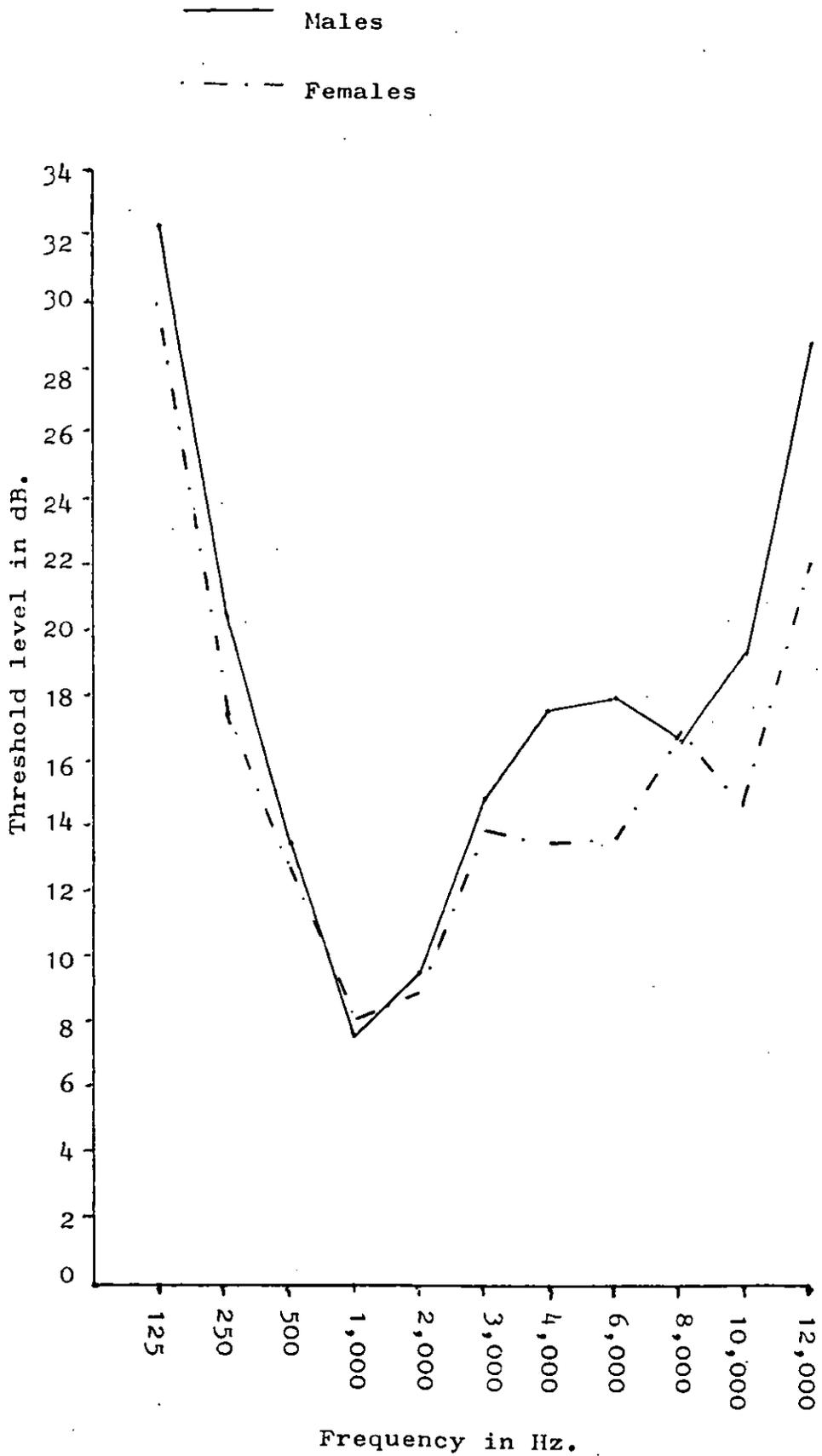
FIGURE 7 : Auditory threshold performance curves for males and females - left ear.
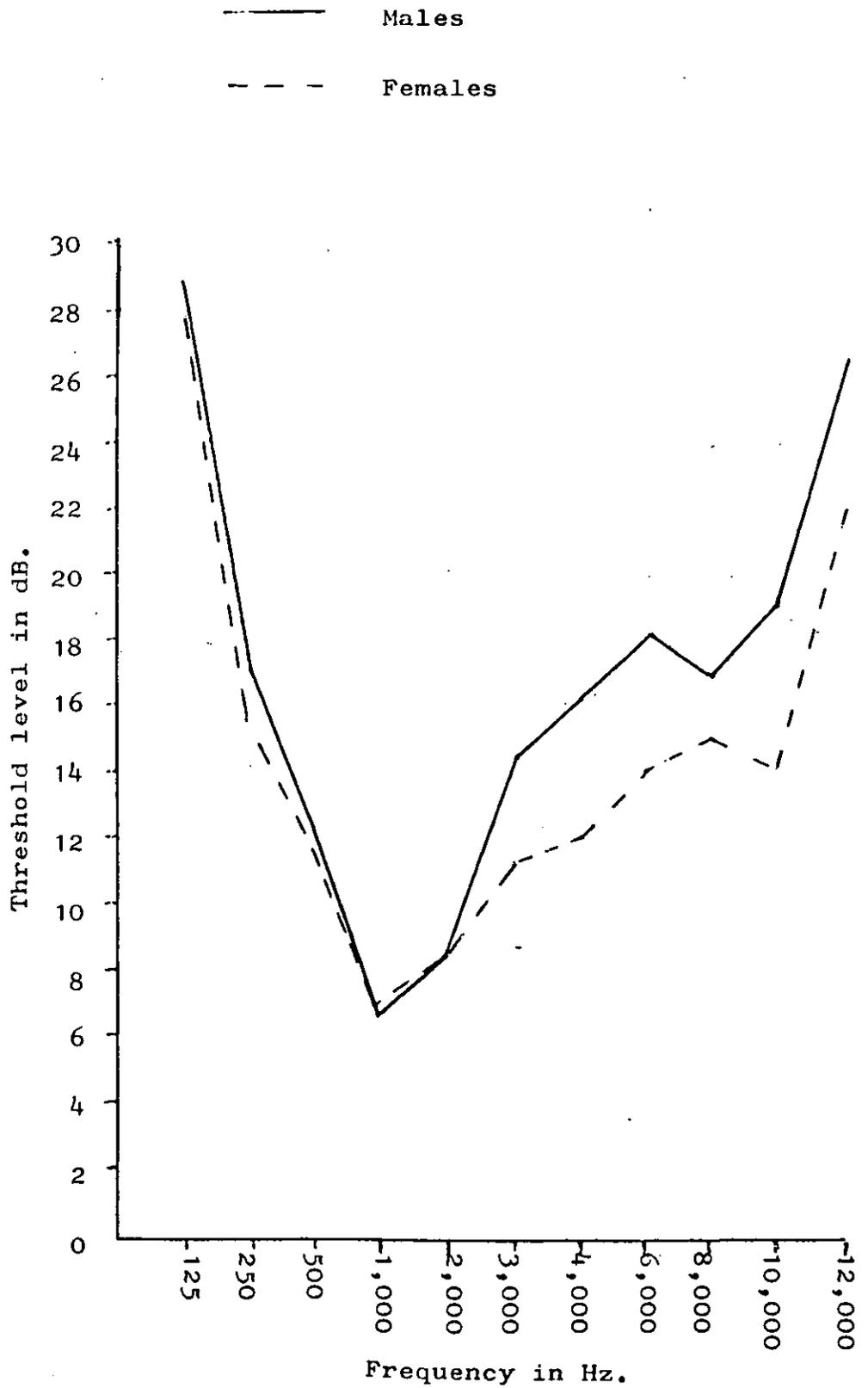
TABLE 26:   Best Ear Performance.

GROUP	LEFT	NO DIFFERENCE	RIGHT
MALES	17	23	10
FEMALES	22	22	6

Only ten subjects in the sample were left-handed (by their own definition), two males and eight females.   No significant relationship could be found between handedness and best ear performance (using the Sign Test).   Subjects with abnormal performance on the threshold test were eliminated for this analysis. This finding is also given by McGuinness (1975).

DISCUSSION

The primary aim of this investigation has been to determine whether or not differences exist between young adult males and females in performance at threshold, subjective reaction to uncomfortable loudness and discrimination in both the auditory and visual modalities.   Data has been presented in the previous section indicating that in at least some of these parameters, significant differences are discernible.   In this section the findings for the auditory modality are discussed in the light of the findings of other studies and current theories of sex differences, and some attempt is made to explain the nature of the source of these differences.

1.   Threshold: The finding that females showed greater sensitivity at threshold for some frequencies is in accord with earlier studies (Corso, 1959;   1963;   Eagles et al, 1963;   Hull et al. 1971;   McGuinness, 1975).   Significant differences at lower frequencies are not reported elsewhere, but the mean performance of males in the study by Corso (1969) is consistently poorer at all frequencies.   The lack of significant differences between the sexes across the whole frequency range highlights the importance of frequency in amplitude detection.

The study by Corso (1959), in which having found differences between the sexes in performance, he controlled for a number of environmental effects but still found significant differences in favour of females at many frequencies, largely negates the validity of cultural

and environmental factors as major determinants of this sex difference
in performance.   Furthermore, the young people used as subjects in this
current investigation were from similar backgrounds and had been
subjected to little or no work experience which might damage the ear.
The likelihood, therefore, that biological factors are involved must
be considered, but the consistency over age, and the fact that females
retain their greater sensitivity rules out the developmental lag
explanation.

Three possible explanations of a biological nature may be advanced
which could give rise to the greater sensitivity of females at threshold
for some frequencies.   One, or all (working together in interaction)
of these arguments may be appropriate:

a. 1.Ward   (1966) found that threshold shifts, which occur following
         presentation of a loud noise, were different in males and females
         depending upon the frequency range involved.   Women are apparently
         more affected at high frequencies, and men at low frequencies.
         Ward suggests that this might be the result of females having
         more delicate middle ear muscles – an argument consistent with
         other findings in sex differences in small and gross muscle systems
         (see Chapter 2).

   2.He further reports that evidence from experiments on cats demonstrates
         that the middle ear muscle operates differentially over low and
         high groups of frequencies.   Anatomical verification for humans of
         this hypothesis would be needed to determine its validity, but some
         support for the idea can be found in the effects of ageing on the
         hearing process.   Studies by Christman (1971) and Tobias (1970)
         have shown that the hearing loss, particularly at high frequency
         threshold, associated with ageing is apparently related to a
         stiffening of the middle ear muscles (tympanus, stapedius) and a loss
         of resilience of the tympanic membrane.

b.   High noise levels over a continuous period of time damages those
         hair cells which respond to high frequency tones (Christman, 1971).
         Thus it may be that the density of such hair cells is greater in
         females at the stapes end of the basilar membrane, where high
         frequency sensitivity is maximal.   Anatomical and histological
         techniques could be used to test this suggestion, but it would seem
         that this hypothesis has not been pursued.

c. The previous two explanations suggest that the greater sensitivity of females may be due to mechanical structure. The difference could, however, be located in such higher centres as the inferior colliculi and the superior gyrus of the temporal lobe. Damage to these centres has been shown to affect both the detection of fine differences between frequencies (pitch discrimination) and between intensity (Evans, 1974; Milner and Teuber, 1968). It may be that females possess greater sensitivity in these areas associated with a greater neuronal development. Hormonal arguments will be dealt with in a separate section, but it is important to note that these are unlikely to be able to account for the difference between the two sexes across the range of age groups. As stated, any or all of these suggestions may provide an explanation, at least in part, of the existence of sex differences in threshold sensitivity levels.

2. Intensity: A significant sex difference was found in the subjective response to intensity with females being more sensitive across all the frequencies tested. Again similar findings have been noted in previous studies, where response to intensity in a variety of tasks has shown differences between the sexes in different age groups (Zaner et al, 1968; Elliott, 1971; McGuinness, 1975). With subjects of a similar age to those tested in this study, McGuinness obtained very similar results to those presented here, despite differences in methodology. She allowed her subjects to control the intensity level themselves, but surprisingly her subjects set lower mean values for 'just uncomfortable' loudness than those obtained in this study (approximately 8 dB for each sex). The data presented by Elliott, using younger subjects, is also remarkably similar.

The significant difference between the sexes in uncomfortable loudness remained relatively constant across the whole frequency range, unlike the findings for threshold, where sensitivity differences were related to particular frequencies. This would seem to lend support for the suggestion made earlier of higher centre CNS involvement rather than differences in peripheral mechanisms. On the other hand it could be argued that some cultural/environmental process is involved. For example, it could be argued that any type of verbal rating scale, like the one described in Chapter 3, could affect the sexes differently, through the operation of some form of semantic bias. Alternatively, it might be suggested that females are exposed less often to high intensity sound levels than males.

The argument that the sexes differ in semantic biases, which could give rise to their employing separate levels of meaning to verbal descriptions, would imply that cultural factors influence the way in which the sexes learn to label their reactions to sound. Because the sexes differ in the way in which they respond to the label 'just uncomfortable intensity', an explanation would be required in which females were somehow protected from noisy environments, perhaps giving rise to some minimal conditioned fear reaction. However, the females in this sample have been brought up in mixed-sex homes, most went to mixed-sex schools and all now live in a mixed-sex residential community, in which few people of either sex have ever been subjected to excessive factory or other work noise. Furthermore both sexes frequently attend noisy "disco" dances, and it must be argued that such an acculturation hypothesis lacks plausibility.

The study by Elliott (1971) in which very similar results were obtained in 'just uncomfortable loudness' to those presented earlier in a sample of children, further militates against accepting a purely environmental explanation. Although linguistic and other biases might well be established early, one would expect either an increase in or regression away from such a bias over a number of years. Instead, the difference between the sexes, measured in dB, in 'just uncomfortable loudness' is remarkably consistent, suggesting that some biological mechanism is involved. The problem may be resolved by studies attempting to alter the bias in children and adults.

As a further argument against the acceptance of a linguistic bias explanation, studies by Fishkin and Blanchard (1964) and Zaner et al, (1968) have demonstrated, using children and adults, that females are more sensitive to intensity changes than males in auditory concept tasks. In these studies, subjects are presented with a sound pattern which varies on one of four dimensions - duration, frequency, laterality and intensity - and they are required to determine which of these is changing. Females are consistently superior at all ages in discerning changes of laterality and intensity. Since these tests require an objective response, either recognition or reproduction, effects due to linguistic biases are eliminated.

Developmental lag hypotheses, which would explain the findings in terms of differences in rates of maturation between the sexes and

predict that such differences would alter over time, may be discounted. The findings noted above in relation to greater female sensitivity to intensity in auditory concept tasks at all ages, and the findings for 'just uncomfortable loudness' of Elliott (1971) in children, in conjunction with those presented in this study for young adults provide evidence of no change with age.

Biological arguments for a mechanical, peripheral difference as an explanation of sex differences in intensity judgement similarly lack plausibility. The differential operation of the middle ear muscle over low and high groups of frequencies reported by Ward (1966) in cats, led to his suggestion of sex differences in the resilience of the middle ear muscles in humans. Whilst it can not be entirely discounted, it cannot account for the consistent differences across all frequencies. Peripheral explanations would imply that females would be significantly more sensitive at some frequencies only, whereas the sex difference is remarkably consistent across the whole frequency range tested.

Thus it would appear that the most probable explanation for differences between the sexes in their subjective reaction to loudness intensity involve the higher central mechanisms, either at sub-cortical levels or at auditory cortex itself. Simmons (1971) suggests that the nervous system codes increments in intensity by a three-fold process of:

      1. an increasing rate of discharge,

      2. by summation due to spreading excitation, and

      3. by a decreasing response latency.

He points out, however, that some of the data do not conform to this explanation. One problem for the explanation of sex differences is that frequency discrimination increases as intensity increases (Henning, 1966; Delse et al, 1972) and many cells at all levels of the system respond to both inputs, showing a maximal sensitivity for varying frequencies at different levels of intensity. The lack of sex differences in pitch discrimination poses problems for this double coding system as an explanation of the differences in the subjective reaction to intensity.

Support for a cortical explanation may be found in the work of Milner and Teuber (1968). Clinical data shows that sensitivity to intensity, which is involved in the localisation of sound and detection of dynamic changes in music, is severely impaired by lesions to the right and left temporal lobes. The left more predominently involves sound

localisation, and the right is involved in detecting changes in dynamics
in musical passages.   Females would appear to be superior in the
performance of both tasks (Schaie et al, 1964;   Shuter, 1964),   thus posing
some problems for hemisphere dominance theories of sex differences.
These propose a strong lateral development of the left hemisphere in the
female, whereas Shuter provides evidence for female superiority in a skill
located in the right hemisphere.   However, it does provide support for
the argument presented earlier that the fine discrimination of intensity
is a property of the cortical systems.

3.   Pitch Discrimination: No significant differences were discernible
between the sexes in performance on the pitch discrimination test used
in this study.   This confirms the reports of studies using musical
aptitude tests (Bentley, 1966;   Shuter, 1968), investigating developmental
changes in children and young adults.   Paradoxically, however, Bentley's
findings, together with those of Roberts (1972) showed that male monotones
greatly outnumber females, and that poor pitch discrimination is a factor
in monotonism, together with deficiencies of tonal memory.   As the sexes
were shown not to differ in these two factors in the present study, it
seems possible that the female advantage has to do with motor processes
and the integration of perception and production.

The finding that ability to discriminate between just noticeable
differences in pitch correlates with the degree of musical training
suggests an important environmental effect on this type of ability.
Nevertheless, innate sensitivity may not be entirely disregarded.   It is not
easy to determine whether musical people undergo musical training because
they have a discriminating ear, or whether musical training makes them more
discriminating.   Bentley (1966) certainly favours a genetic determination
of musical ability, and some support for this may be provided by the
finding that a number of subjects with no formal musical training had
excellent scores on this test.

THE MENSTRUAL CYCLE

Before discussing the possible effects of the menstrual cycle, and
in particular the female hormones, on the parameters investigated, it is
perhaps necessary to briefly describe the hormones and the hormonal level
changes asssociated with the menstrual cycle.
    Three groups of sex hormones - androgens, oestrogens and progestogens -
are detectable in the blood plasma of adult females.   All are steroid

hormones with a similar structure, but differing in the number of carbon atoms per molecule (androgens 19, progestogens 21 and oestrogens 19). The androgens are more commonly associated with males and androgen levels are comparatively low in females. The two sex hormones with the highest concentration levels in females are oestradiol (an oestrogen) and progesterone (a progestogen). Both are produced by the ovary, and the adrenal glands also produce some of each compound, in addition to smaller quantities of androgens. When an adult female is not pregnant, both oestradiol and progesterone show cyclical changes in the levels of production by the ovary, giving rise to the menstrual cycle. The hormonal changes accompanying this cycle show a peak in the level of oestradiol occurring at ovulation, followed by elevated progesterone levels in the subsequent phase (when oestrogen levels are also high). A detailed description of the hormonal changes in the human menstrual cycle is given by Vanderwiele et al, (1970).

Evidence for hormones as substances which can alter sensory thresholds came initially from the olfactory studies of Le Magnen (1950: 1952), who reported changes in the ability to smell musk (exaltolide) during the menstrual cycle. Other olfactory studies confirmed that changes of olfactory sensitivity occurred during the menstrual cycle (Virling and Rock, 1967; Schneider and Wolf, 1955; Schneider et al, 1958). Glanville and Kaplan (1965) showed that sensitivity to the tests of quinine and thioracil also changed during the menstrual cycle. For temperature, Kenshalo (1970) found that the detection threshold fell at ovulation and rose again at the onset of menstruation, while pain threshold changes have been measured by Buzzelli et al, (1968), who found that women were less sensitive to pain around the time of ovulation. In audition, evidence has been presented by Semszuk et al. (1967) that acoustic sensitivity is greatest around ovulation. Pitch estimation was found to change in a different way, with lower frequency estimates at both around menstruation and around ovulation - a bi-menstual cycle (Wynn, 1971; 1972). Baker and Weiler (1977) studied the auditory threshold levels of two groups of females - one normally menstruating, the other taking an oral contraceptive pill - and one group of men over a six week period and found that the females taking a birth control pill were more sensitive throughout than the other two groups, and that the normally cycling females were more sensitive during the pre-ovulatory phase of their cycle. The data presented in Table 10 fails to show a significant different at threshold between any of the three sub-groups into which the females were divided in this study

(A - those taking an oral contraceptive, B - those in the pre-ovulatory phase, and C - those in the post-ovulatory phase), but the means for those in the pre-ovulatory phase are lower at most frequencies, so that some support is perhaps provided for the findings of Baker and Weiler. Since the females in this study were tested on one occasion only, one could not expect to replicate the findings of Baker and Weiler (who, incidentally, used only four subjects per group), and certainly no evidence was found to suggest that females taking an oral contraceptive had lower thresholds than the other groups. Thus it would seem that more research is required to completely substantiate their findings, but some indications are present that suggest an effect of hormonal changes on auditory sensitivity (especially since lower means were also found for sub-group B in the loudness test).

Comparison of the three sub-groups with the males does present an interesting feature. Significant differences at threshold between the males and the pre-ovulatory group are present at more frequencies than between the males and the other two sub-groups. This lends support to a higher centre explanation of differences between the sexes, perhaps in terms of a greater responsivity to auditory signals during the pre-ovulatory phase as a result of chemical changes in the receptor mechanisms, brought about by the cyclical hormonal changes. Table 13 indicates that similar results are obtained for loudness, and again suggests that fluctuating chemical changes affect the sensitivity of the auditory receptor mechanisms at the cortical or sub-cortical level. This can not be the only reason for differential performance between the sexes, however, since Corso (1959) has shown that sex differences exist at all age levels, even before puberty.

The way in which the female sample was sub-divided made it impossible to consider Wynn's findings (1977; 1972) for pitch discrimination in this study.

CORRELATIONAL ANALYSIS
The suggestion by Garai and Scheinfeld (1968) that females display an 'auditory stimulus hunger' and males a 'visual stimulus hunger' would seem to imply that hearing and vision are unitary phenomena, in which performance in the parameters investigated in this study - absolute threshold, uncomfortable loudness and discrimination - are closely related. This would appear to be an important question, but it is one that has received only marginal attention by many researchers. If hearing is a

unitary phenomenon then one would expect high correlations to be obtained for performance levels of the tasks investigated in this study, and a lack of sensitivity at absolute threshold, for example, would imply poor discriminative ability. On the other hand, if performance in the various auditory tasks is not correlated it would imply that hearing consists of a number of differentially sensitive input channels.

Where studies have investigated more than one auditory task, they have usually related absolute threshold for intensity to the slope of loudness function. Hood (1968) has presented evidence for one frequency level only that the two parameters are closely related. Schneider et al. (1972) suggest that some effect of recruitment, affecting the angle of loudness slope, is part of all normal hearing, based on the finding that at low frequencies, where thresholds are high, the angle of the slope is much steeper. Stephens (1971) supplies evidence that for subjects with normal hearing a physiological recruitment and increased slope occurs at low frequencies (250 Hz) but not at high frequencies (4,000 Hz), but for subjects with true clinical recruitment this finding is reversed. Although these studies suggest that certain parts of the threshold curve do relate to judgements of intensity, they do not provide comprehensive information across a wide range of frequencies.

The results show significant correlations for the total sample between threshold and subjective reaction to loudness in 6 of the 8 frequencies tested (250 Hz: $p > 0.01$; 500 Hz, $p > 0.01$; 3,000 Hz, $p > 0.01$; 4,000, $p > 0.01$; 6,000 Hz, $p > 0.01$; 8,000 Hz, $p > 0.05$), suggesting that performance in the two parameters is related. Surprisingly, however, no significant relationship could be established for 1,000 Hz (the frequency used by Hood, 1968) or 2,000 Hz. Furthermore, when the two sexes are separated, no consistent pattern presents itself, relationships being established for males only at some frequencies, and females only at others. However, although the situation is less clear than one would wish, it does seem that some relationship does exist between the two parameters, at least for some frequencies.

Correlations between pitch discrimination and absolute threshold at 500 Hz and 1,000 Hz (the two reference tones used) similarly show no consistent relationship for each sex, but again a significant relationship ($p > 0.05$) is obtained for the total sample at each frequency. Correlations are again low, but there is an indication that performance

in the two parameters is related, and performance at threshold may be a factor in predicting the ability to determine 'just noticeable differences' in pitch. The lack of consistency in the results, however, again limits the presentation of this argument with any real conviction.

Correlations between performance at threshold for different frequencies were surprisingly inconsistent across the whole range of frequencies for both sexes, although in most instances a high significant correlation was obtained. This conforms to the findings of Corso (1967). It may therefore be more profitable to consider sensitivity at threshold as a function of frequency, rather than across the total range of frequencies. Only in uncomfortable loudness judgement are correlations high and significant across the whole frequency range, providing support for the earlier suggestion that there are sub-cortical or cortical processes involved and/or that the effect is due to some other psychological process.

From the correlational analysis of the auditory data, then, there would appear to be no qualitative unity to argue in a conclusive manner that hearing is a unitary phenomenon, in which the performance of different tasks is closely related. This poses some problems for the concept of an auditory stimulus hunger as proposed by Garai and Scheinfeld (1968) for females. It also raises questions about the validity of some current theories of personality, and we shall be returning to this discussion later.

SUMMARY

The findings demonstrate that females show greater auditory sensitivity at threshold than males in a number of frequencies, particularly those with a higher pitch. Females also set consistently lower levels of intensity as being 'just uncomfortable' at all frequencies. These findings are in accord with previous studies (Corso, 1959; Eagles et al. 1963; Hule et al. 1971; Elliott, 1971). No difference between the sexes was found in pitch discrimination, but performance on this task correlated significantly with the degree of musical training the subject had had.

Whilst this experiment did not include the testing of females throughout the menstrual cycle, when the females were grouped into categories according to their stage in the cycle when tested, some significant differences were obtained. A tentative support for Baker and Weiler's (1977) findings that hormonal levels are implicated in differences in performance between the sexes in auditory threshold is therefore provided.

Correlational analysis showed little relationship between the tasks investigated, and it is tentatively concluded that hearing is comprised of a number of qualitatively different sensitivities. This poses problems for personality theory and the concept of a 'stimulus hunger', and these will be explored in greater depth at a later stage.

CHAPTER 5.

THE VISUAL EXPERIMENTS

INTRODUCTION

In the preceding chapter data relating to differences in performance between the senses in three auditory parameters has been presented and related to the findings of other studies.   In this chapter data for the same parameters - threshold, intensity and discrimination - in the visual modality is presented.   Of these three parameters only the latter, as represented by tests of visual acuity, has been investigated to any real extent, with the findings demonstrating a consistent male superiority (Roberts, 1964; Burg and Hulbert, 1961; Burg, 1961; McGuinness, 1975). Threshold data has been presented by Ippolitov (1972) and McGuinness (1975), the former showing a male advantage, and the latter a female advantage, while Diamond et al. (1972) report significant differences between females in the pre-ovulation and post-ovulation phases, with sensitivity higher during the latter.   Reaction to intensity (brightness) has been studied by McGuinness (1975) who found that males set lower levels as being 'just uncomfortable" than females.

Thus the visual modality would appear to be both less well-researched and more contentious than audition.   It is hoped that the findings of this study will both provide more information and go some way to resolving the problems in this modality.

1.   Threshold: a. Dark Adaptation Rate

As indicated above, findings in visual threshold studies have been contradictory.   Ippolitov (1972) presents raw data by sex, which when analysed shows a male advantage at absolute visual threshold, but he reports no details as to the type of apparatus, viewing distance or type of presentation used, so that it is difficult to draw conclusions from his findings.   McGuinness (1975), on the other hand describes her experiment and apparatus (which she had designed) carefully.   Her subjects were presented with stimuli in one of four fields at gradually decreasing intensities (measured using a photometer) over a period of thirty minutes. She found an over-all superiority for females in all four fields, but a statistical significance in only one (the 'down' position).

Because of the anomalies presented in these two studies the standardised 'Admiralty Adaptometer' test was used in this study.   Table

27 shows the mean time in minutes that each group took to see each
aperture, down to aperture 6 (no subjects went below aperture 5 in the
time allocated for the test), together with the standard deviation and
standard error of the mean.   No significant differences were revealed
between the groups in the mean time taken to reach any aperture by
application of the 't' test.   (Significant differences are revealed,
however, between males and females when the latter are divided into
the three menstrual cycle sub-groups, as will be seen later).   This
information is presented graphically in Figure 8.

Individual scores varied considerably between the two groups.
For example one female subject took only 4.50 minutes to see Aperture 16,
whilst one of the males took 20.17 minutes to adapt to the same aperture.
Similarly, not all subjects reached aperture 6, one subject reaching only
aperture 12 in the thirty minutes, whilst 8 subjects reached aperture 5.
Figure 9 shows the number of males and females to successfully adapt to
each aperture, and it is interesting to note that more males than females
reached apertures 8, 7 and yet more females successfully adapted to
aperture 5.   The data obtained conforms with the norms given for this
test (A.R.L./N.2/0.358), based on data obtained from 500 subjects.   It
will be noted that the figures obtained in this study are slightly higher
than the norms (Table 28) which may perhaps be due to the age of the
subjects tested (in the normative date only 6 out of 500 subjects are
reported as having attained aperture 5).   No description of the 500
subjects tested in the Admiralty sample is given.

TABLE 28   Norms for Dark Adaptation using the Admiralty Adaptometer
            (from A.R.L./N2/0.358)

Description of night vision	Grading on Adaptometer	Approx. percentage of individuals with grading
Above average	5, 6 & 7	13%
Average	8, 9, 10 & 11	70%
Below average	12 & 13	12%
Bad	14 and above	5%

TABLE 27: Dark Adaptation Rate for Males and Females
(Mean Time. S.D. and S.E.M.)

APERTURE	GROUP	MEAN (in mins)	S.D.	S.E.M.
16	M F	10.91 10.76	2.79 2.68	.39 .38
15	M F	13.01 12.86	2.83 2.93	.40 .42
14	M F	14.86 14.73	2.86 3.27	.40 .46
13	M F	16.75 16.62	3.06 3.51	.43 .50
12	M F	18.65 18.62	3.23 3.95	.46 .56
11	M F	20.43 20.58	3.08 4.18	.44 .59
10	M F	22.17 22.42	3.35 4.54	.48 .64
9	M F	23.81 24.14	3.31 4.71	.48 .67
8	M F	25.47 24.94	2.90 4.45	.44 .71
7	M F	26.68 25.76	2.25 4.08	.37 .75
6	M F	28.35 27.28	1.48 2.97	.27 .65

The Mean Aperture obtained by the males and females in this study are presented on Table 29, together with the standard deviation and standard error of the mean for each group. Again the 't' test revealed no significant difference, so that statistically the data presented here supports the findings of neither Ippolitov (1972) nor McGuinness (1975), and suggests that there is no difference between the sexes in scotopic visual threshold. As one would expect high correlations were obtained between the time taken to adapt to the first aperture (No.16) and the final aperture attained (Men, 0.70; Women, 0.44; Total Sample, 0.56). All correlations were significant $(p > 0.01)$.

TABLE 29. Dark Adaptation: Mean Final Aperture for Males and Females

GROUP	MEAN APERTURE	S.D.	S.E.M.
MALES	6.84	1.38	.20
FEMALES	7.12	1.36	.20

2. Intensity: Brightness

In the experiment in which subjects were asked to look directly at a light source and adjust it to a level of light which they felt could be looked at without discomfort for an indefinite period McGuinness (1975) concluded that males were less tolerant of light than females. Questions may be raised, however, by her methodology, and in this study a more typical glare test was employed, with all readings being expressed in Kilocandelas/m^2 (luminance of glare source, other luminance levels being held constant). As with the auditory tests, subjects displayed a remarkable consistency over the three stimulus presentations in their judgement of 'just uncomfortable' glare in spite of the obvious problems of light adaptatation, and the mean of the three presentations did not differ significantly from their initial assessment. The range within the total sample was considerable, however varying from 3.63 Kilocandelas/m^2 to 65 Kilocandelas/m^2. Statistical analysis employing the 't' test revealed no significant difference between the mean values obtained for the male and the female groups, which are presented in Table 30, together with the standard deviation and standard error of the mean for both sexes. There is, nevertheless, quite a large difference between the two means,

FIGURE 8:   Dark adaptation rate ; males and
            females.
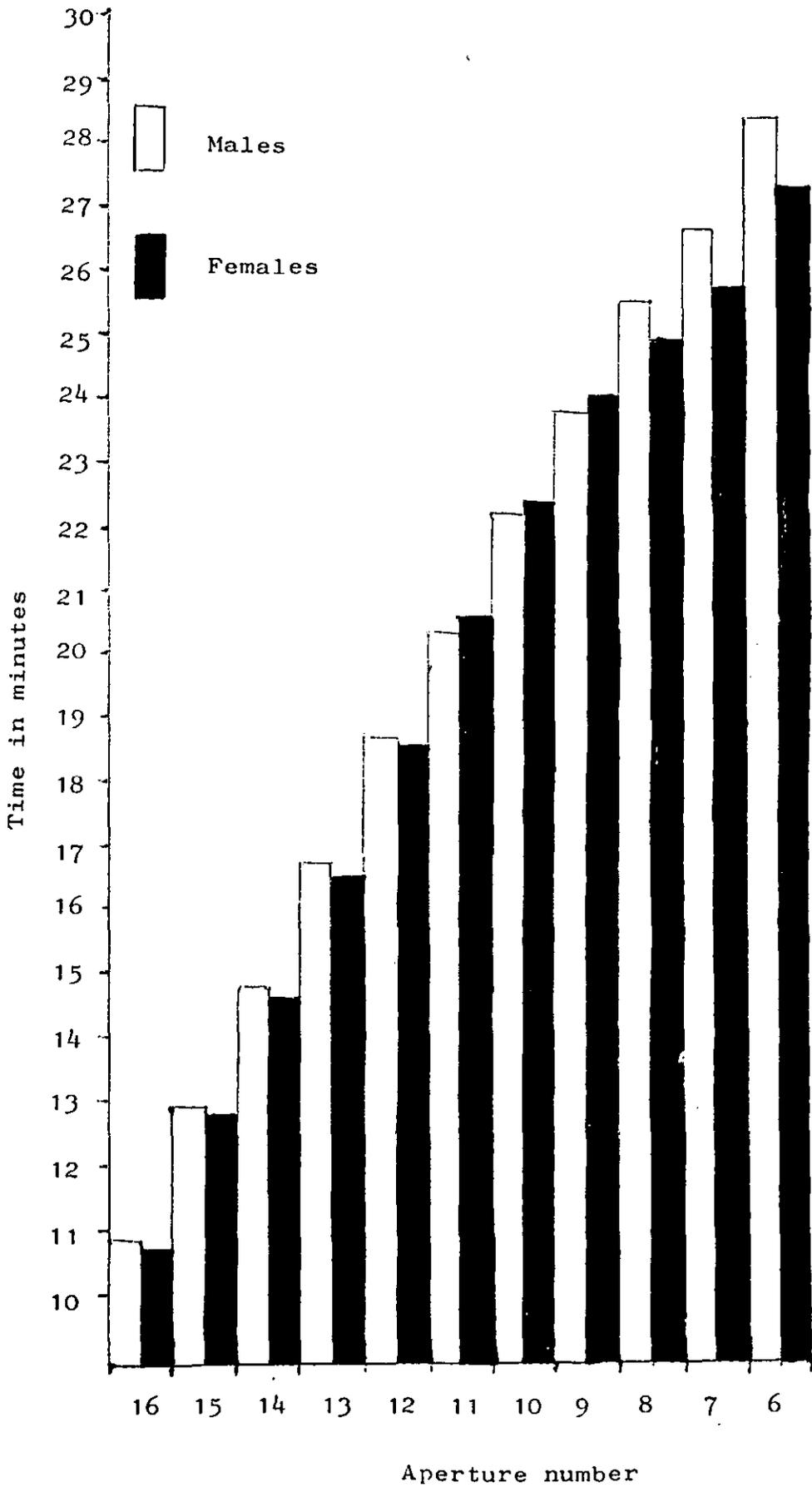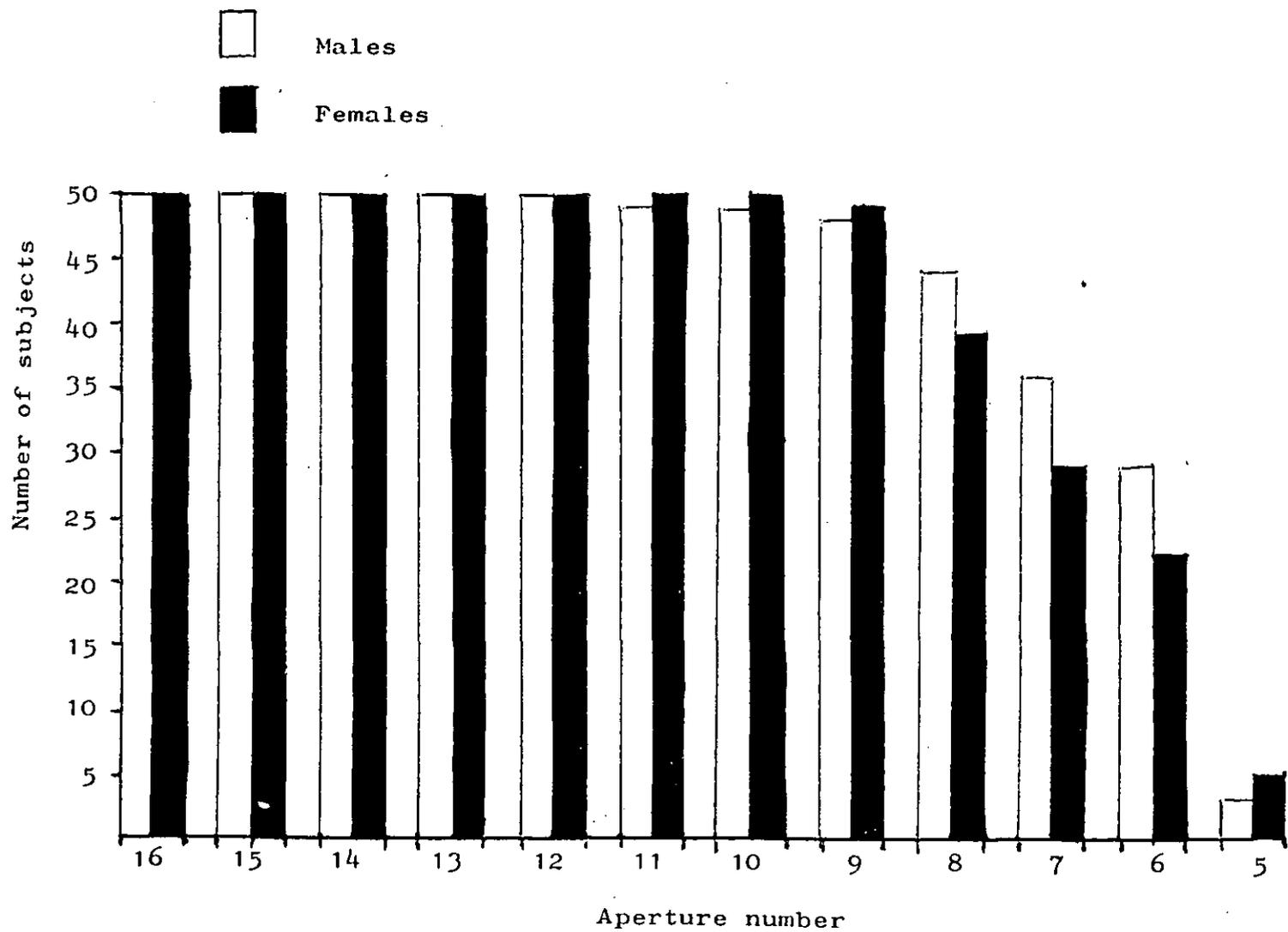
Aperture number

FIGURE 9 : Number of males and females to successfully adapt to each Aperture - Dark Adaptation Test.

and division of the female group into the three menstrual cycle sub-groups does reveal a significant difference in favour of the males, as will be seen later.

TABLE 30. Glare: Mean, Standard Deviation and Standard Error of the Mean for Males and Females (in Kilocandelas/m^2)

GROUP	MEAN	S.D.	S.E.M.
MALES	26.82	18.24	2.58
FEMALES	29.95	20.21	2.86

3.   Discrimination. - Visual Acuity.

As has already been indicated, a large body of normative data exists for visual acuity, demonstrating a consistent superiority of performance by males (Roberts, 1964; Burg and Hulbert, 1961; McGuinness, 1975). The problems of testing visual acuity are discussed elsewhere, and the choice of both the Snellen Letter Test and Landolt Ring Test explained.

The data obtained from each test was combined to provide an over-all score for each individual in visual acuity. Performance in each test was remarkably similar, few subjects obtaining a different score in the two tests. The charts provided for scores ranging from 5 to 60 minutes of arc, visible from 6 metres, and their construction is such that the data derived is not ordinal, and could not therefore be analysed using parametric methods.

The combined "best eye" score was selected for statistical analysis, using the Mann-Whitney U test. This provided a z score of 2.72, indicating a significant difference in favour of the males (p>0.01). Mean acuity scores were 6/6 for the males and 6/9 for the females (mode scores 6/5 and 6/6 respectively). The distribution of performance in visual acuity for both sexes is shown in the histogram presented in Figure 10. From this it can be seen that the difference in visual acuity is largely due to more females than males scoring at the high end of the scale, (scores of 6/12 or worse: Males =2 Females =6) whilst many more males than females achieved the lowest score (6/5: Males =26; Females =12).

FIGURE 10 : Histogram of distribution of performance of males and females on visual acuity test.
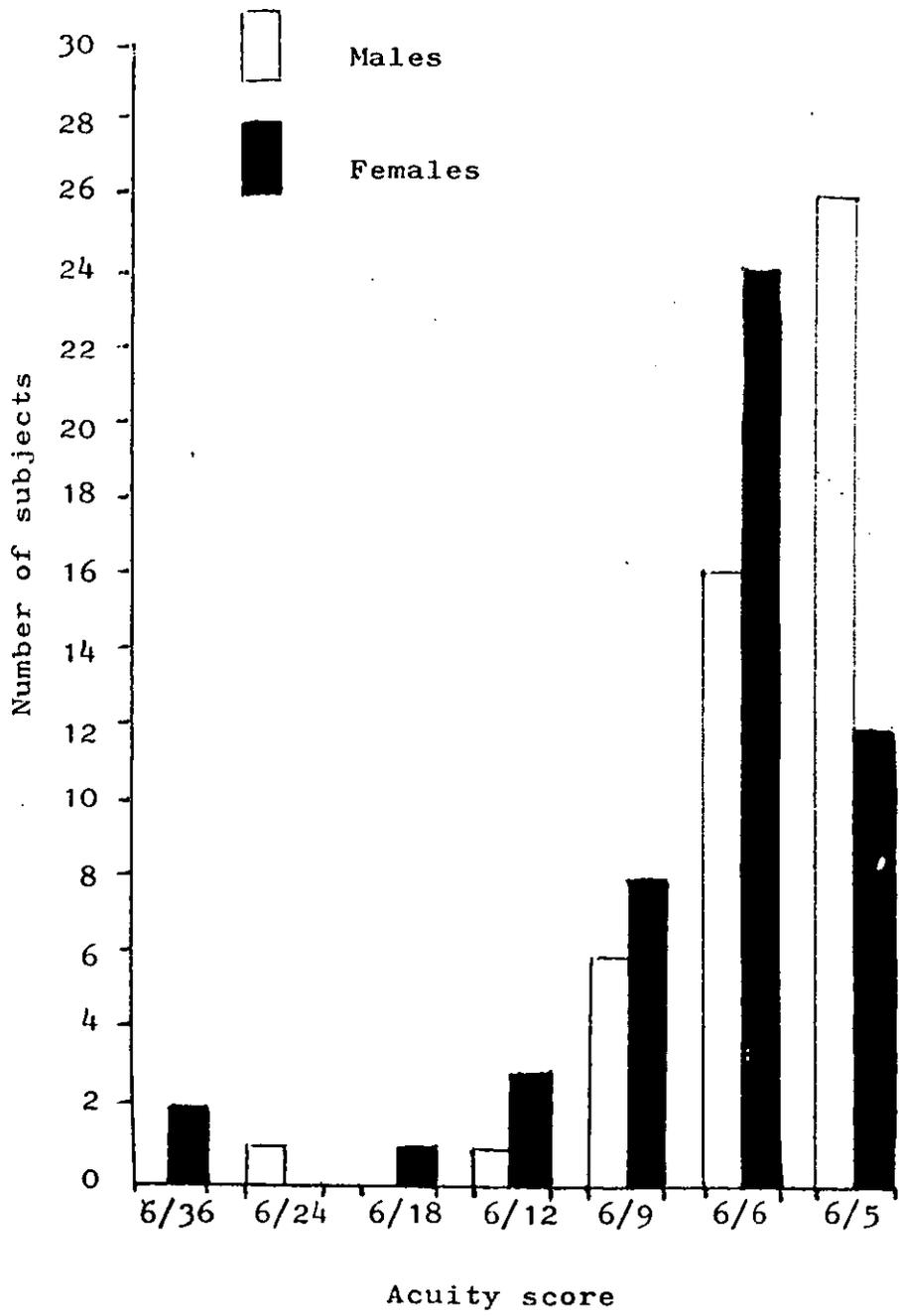
Inter-Modality Correlations

In previous studies of the visual modality involving within mode correlations, there has been a noticeable lack of stable correlations, showing little relationship between measures of threshold, visual after-effects, speed of conditioning and reaction to intensity (Ippolitov 1972, Nebylitsyn & Gray 1972; Strelau 1972). Similarly the lack of stable, significant inter-modality correlations derived from the auditory experiments already presented, would lead one to predict a similar lack of relationships between the visual parameters tested in this study.

As for the auditory modality, within mode correlations for vision were computed, using the Pearson's Product-Moment Correlation formula, for all data except that involving visual acuity correlations. The sexes were first analysed separately, and then a correlation for the total group determined. Owing to the non-parametric nature of the visual acuity data, correlations involving this data were computed using the Spearman's Rank-Order Test (rho).

1. Threshold and Intensity (Glare). A matrix of correlations between tests in visual threshold and glare is presented in Table 31. No consistent relationship is discernible between the two parameters, but there are some interesting significant relationships discernible.

The relationship between the time taken to successfully adapt to Aperture 16 and the final aperture attained has already been discussed, with high significant correlations being obtained. The relationship between each of these figures and the glare value is interesting. A significant relationship has been obtained between the final aperture and glare BCD for females, but not for males. On the other hand, the relationships for all groups is significant between glare and the initial rate of adaptation, with the relationship for males being higher than that obtained for females. This relationship was probably brought about by the methodology employed in the glare test. It will be remembered that this test was given after the subject was fully dark adapted. Thus it would appear that the rate of light adaptation was a factor in this test, and since this is a reverse process to dark adaptation, a relationship between these two processes is established.

TABLE 31.   Matrix of Correlations Between Tests in Visual
             Threshold and Glare.

TEST	GROUP	DARK ADAPTATION APERTURE 16	DARK ADAPTATION FINAL APERTURE
DARK ADAPTATION FINAL APERTURE	Males	.70 +	
	Females	.44 +	
	Total	.56 +	
GLARE	Males	.35 +	.11
	Females	.23 *	.21 *
	Total	.29 *	.17 *

+ significant p > 0.01   * significant p > 0.05

Correlations (rho) obtained between visual acuity and dark adaptation tests are presented in Table 32.   As can be seen correlations are again low, but the relationship between visual acuity and threshold, as expressed by the final aperture attained in the dark adaptation test, is significant. This was unexpected since one is a function of foveal, photopic vision and dark adaptation is a scotopic visual process.   However, the nature of the adaptometer test requires discrimination of the pointer on the dial, thereby relating to discrimination in the acuity test.   It does suggest however, that in this discriminative function a relationship exists between both photopic and scotopic visual processes.

TABLE 32.   Correlations Between Visual Acuity and Threshold Tests.

GROUP	DARK ADAPTATION APERTURE 16	DARK ADAPTATION FINAL APERTURE
Males	.01	.22*
Females	.05	.40 +
Total	.03	.33 +

* significant p > .05   + significant p > .01

3.   Glare and Discrimination.   The relationship between glare and visual acuity can be seen in Table 32.   There is an overall relationship for the total group (p > 0.05) and a significant relationship for males (p > 0.01), but not for the females.

TABLE 33. Correlations Between Glare and Visual Discrimination

GROUP	
Males	.31 +
Females	.08
Total	.15 *

+ significant p > .01
* significant p > .05

In general the within mode correlational data provides support for the prediction made at the beginning of this section that visual functions are not related in any stable and consistent manner, with the exception of both dark adaptation and light adaptation rates and acuity and absolute threshold. This latter relationship was unexpected, but it is interesting to note that a similar relationship was observed by McGuinness (1975) using a different type of threshold test.

The Menstrual Cycle and Vision

As with the auditory modality research evidence has indicated that the cyclical hormonal changes which accompany the menstrual cycle influence visual sensitivity in normally cycling females. Diamond et al. (1972) claims that visual sensitivity at threshold is at its greatest at approximately the time of ovulation, continues to stay high until menses, and then declines abruptly at the onset of menstruation. These changes were not seen in women taking an oral contraceptive pill, and no cyclical pattern was evident in men. These claims are made on the basis of very small sample sizes, however (N=4 in each case), and absolute threshold was not tested, since the subjects had dark adapted for only 8 minutes prior to testing. Evidence concerning other visual parameters does not appear to be available.

Data for the three female sub-groups already discussed (A. those taking an oral contraceptive, B. the pre-ovulation phase group and C. the post-ovulation phase group) was therefore analysed to determine whether any menstrual cycle influence on visual sensitivity was apparent.

1. Visual threshold. The data for the dark adaptation test is presented in Table 34 which gives the mean final aperture to which each sub-group successfully adapted, together with the standard deviation and

standard error of the mean.   As can be seen females in the pre-ovulation
group (from onset of menses to mid-cycle) failed to obtain the same
adaptation level attained by the other two sub-groups, and significant
t-values were obtained between sub-group A and sub-group B (t = 2.94,
p > 0.01) and between sub-group C and sub-group B (t = 4.76, p > 0.001).
These findings are consistent with those of Diamond et al (1972), who
also noted a lower visual sensitivity.

TABLE 34.   Dark Adaptation: Final Aperture Attained - Mean, S.D.
and S.E.M. for Three Female Sub-Groups.

GROUP	MEAN	S.D.	S.E.M.
A - oral contraceptive	6.64	1.43	.43
B - pre-ovulatory	8.00	1.03	.24
C - post-ovulatory	6.33	1.14	.25

Figure 11 shows the differences in the rate of dark adaptation
between the three female sub-groups and the males, giving the mean.
time it took for each group to adapt to Apertures 16 - 7.   It will be
noted that the pre-ovulation sub-group are consistently slower in their
adaptation rate than all other group-s.

Comparison of each of the three female groups with the males in
dark adaptation reveal a significant difference in performance between
the sexes which was hidden in earlier analysis.   Whilst no significant
difference is revealed between the mean final aperture attained by the
males and sub-groups A and C, there is a significant difference between
their score and that of the pre-ovulation female group (t value = 3.40,
p > 0.01).   This would perhaps explain the findings cf Ippolitov (1972)
of a male superiority (he provides no information about the female
sample in terms of the menstrual cycle).   Certainly over-all, the
findings of this study are consistent with and provide support for those
of Diamond et al (1972).

2.   Glare.   Since it has already been shown that a relationship exists
for females between dark adaptation and glare in vision, one would expect
group B to be more tolerant of glare than the other two groups.

FIGURE 11 : Dark adaptation rate for males and three female sub-groups.
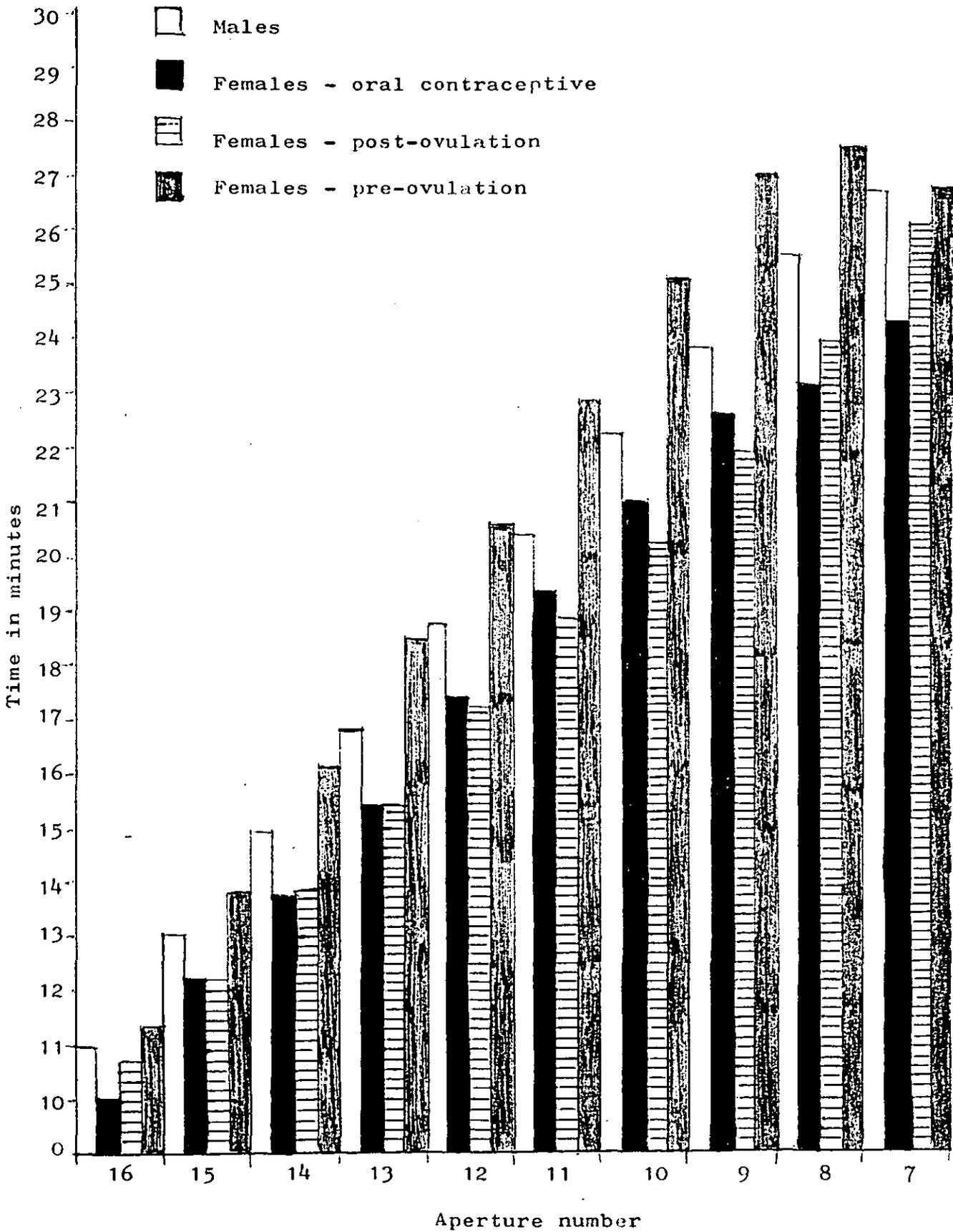
Examination of Table 35 which presents the mean glare source luminance in Kilocandelas/m^2 standard deviation and standard error of the mean for each group, shows that this is in fact the case, with a significant difference being revealed by statistical analysis between the post-ovulation and pre-ovulation groups (t = 2.39, p> 0.05). No significant difference was obtained between group A and either of the two normally cycling groups.

TABLE 35. Glare: Mean, Standard Deviation and Standard Error of the Mean for Three Female Sub-groups (in Kilocandelas/m^2)

GROUP	MEAN	S.D.	S.E.M.
A	28.67	22.21	6.70
B	36.95	21.13	4.61
C	22.56	15.58	3.67

Comparison with the male group again reveals a significant difference between the sexes, which was not observed in the earlier analysis. No difference was observed between groups A and C and the males, but a significant difference was found between the males and the pre-ovulation group, with the males being more sensitive (t = 2.04, p> 0.05). This result is similar to the findings obtained for absolute visual threshold.

3. Discrimination.

For visual acuity the Mann - Whitney U test was again employed to test for the significance of differences between the three group-s. No significant differences were found, and it was felt that a more sensitive test of visual acuity would be needed to determine the existence of any differences (which are likely to be small).

The results suggest, then, that certain visual parameters do show the effect of cyclical changes within the normally menstruating female. More conclusive results would, of course, be provided if the females within the sample had been tested (with a group of males) over the whole course of their cycle, as in Diamond et al's (1972) study. This could not be attempted in this study, but the results do provide supportive evidence for other studies.

Personality and the Visual Modality

Correlations between scores on the Eysenck Personality Inventory (Eysenck and Eysenck, 1964) of both males and females in extroversion - introversion and neuroticism - stability and their performance scores in visual tests are presented in Table 36. Relationships in the main, are low, but some significant relationships are present and require some discussion.

The significant relationship between glare (intensity) tolerance and neuroticism for females (a negative correlation between the score for neuroticism and the level of glare) is surprising in that it does not hold for both sexes, and was not apparent in the auditory modality, where extraversion and tolerance were related for females.

The only other significant relationships are between visual acuity and neuroticism in females, with more neurotic females apparently having better visual acuity.

TABLE 36: Correlations between personality factors and visual test performance.

EXTRAVERSION	DARK ADAPTATION APERTURE 16	DARK ADAPTATION FINAL APERTURE	GLARE	VISUAL ACUITY
Males	.12	.01	.13	-.04
Females	-.01	-.14	.08	.09
Total	.07	-.08	.05	.01
NEUROTICISM				
Males	-.12	-.03	.01	.07
Females	-.01	-.17	-.31	-.22*
Total	-.07	-.08	-.14	-.08

* significant p. 0.05

Eye Colour and Visual Sensitivity

In order to test whether or not eye colour affected visual sensitivity (it often being popularly supposed that blue eyes are more sensitive than brown eyes to light), note was taken of each subject's eye colour. In the total sample of 100 subjects, 46 had blue eyes, 32 had brown eyes and 22 were assigned

to a third group containing those not easily assigned to the other
eye colour groups, (who usually described their eye colour as hazel).
Using the 't' test in all instances except visual acuity, where the
Mann - Whitney U test was employed, statistical analysis revealed no
significant differences between the performance of the blue-eyed or
brown-eyed groups in any visual parameter.   Only one significant
difference was found - between the blue-eyed group and the third
('hazel') group in dark adaptation/visual threshold (p>0.02) in
favour of the latter.   It would seem safe to conclude, therefore,
that eye colour is not an important determinant of visual sensitivity.
Table 37 shows the mean values, standard deviation and standard error
of the mean for each group in all the visual tests except visual acuity.

TABLE 37:   Mean, Standard Deviation and Standard Error of the Mean
            in Visual Parameters according to Eye Colour.

PARAMETER	GROUP	MEAN	S.D.	S.E.M.
DARK ADAPTATION FINAL APERTURE	BLUE	7.23	1.54	.22
	BROWN	6.91	1.30	.23
	HAZEL	6.43	.98	.21
GLARE (in Kilocandelas /m^2)	BLUE	28.62	20.03	2.95
	BROWN	28.38	18.56	3.28
	HAZEL	28.05	19.32	4.12

Laterality and Vision

Lateral preference in vision presented similar anomalies to those
found in the auditory modality.   The two eyes were measured separately
in the test for visual acuity.   The readings obtained for individual
subjects were frequently the same for each eye.   Table 38 shows the
distribution of male and female subjects according to eye preference.

TABLE 38. Best Eye Performance in Visual Acuity

TEST	GROUP	LEFT	NO DIFFERENCE	RIGHT
VISUAL ACUITY	Men	7	30	13
	Women	8	31	11

Significant correlations were obtained between left eye and right

eye performance (p >0.001 in all cases) for this test, and these are presented for males, females, and the total sample in Table 39. No significant differences between right and left eye performance was obtained for males or females.

TABLE 39: Left and Right Eye Correlations in Visual Acuity

TEST	MALES	FEMALES	TOTAL
VISUAL ACUITY	.85	.78	.80

DISCUSSION - Differences Between the Sexes in the Visual Modality.

As was the case with the auditory modality, some parameters showed a difference in performance between the sexes, whilst others did not. Unlike the auditory modality, however, no significant differences were obtained for sensory sensitivity at threshold nor for subjective reaction to intensity. In this section these findings are discussed, but before doing so, it is important to dismiss the old myth that eye-colour determines visual sensitivity. It can be seen from the data presented earlier that eye-colour has no influence on visual sensitivity in any visual parameter.

1. a. Threshold - Dark Adaptation: The finding in this study that no overall significant sex difference was apparent in scotopic visual threshold runs counter to the findings of both Ippolitov (1972) and McGuinness (1975). A difference was apparent when analysing the female data in terms of the menstrual cycle, but this will be discussed in a later section.

Ippolitov does not, in fact, analyse his results by sex, but presents all his raw data, including the sex of each subject. Statistical analysis of this data reveals that males have significantly lower absolute visual thresholds than females (p> 0.05). Table 40 shows the range and mean scores for his subjects, who were dark adapted for up to 40 minutes and tested over periods from 50 to 75 minutes for a number of trials in each case. As no further details of the experimental design are available in English, this makes further comparison with the present experiment difficult. Certainly in terms of both the apparatus and experimental design used, the test is more sensitive than that employed in this study - which did, in fact, provide a non-significant difference

between the mean scores in favour of the males, and to this extent is
in line with that of Ippolitov.   Perhaps a longer test-period would
have provided more significant results.

TABLE 40:   Raw Data - range, mode, means from Ippolitov (1972).
Scores are in Apostilbs at Visual Threshold.

	RANGE	MODE	MEAN
MALES	40 - 105	80	74
FEMALES	45 - 200	85	96

McGuinness (1975) investigated sex differences in visual threshold
using apparatus which tested her subjects in four visual fields (up,
down, right and left), and found a significant difference in favour of
the females in the down position only (but the mean scores of the females
were superior in all positions). McGuinness further maintains that
while sex differences at threshold were not sufficiently distinct to
produce a significant effect when the data were analysed using an ANOVA,
a significant difference in favour of females was found when assessing
mean data over all positions tested, when subjects with normal acuity
were assessed separately.   On the basis of these findings McGuinness
concluded that females may have certain differences in rod function,
either due to greater concentration at certain points across the retina,
or more efficient rod performance.

On the basis of both Ippolitov's data and that presented in this
study, the argument for more efficient overall rod performance in
females may be discounted.   The proposal that there might be differences
in rod concentrations at certain points across the retina might, perhaps,
account for the difference found by McGuinness in relation to the
different visual fields, which were not investigated in this or Ippolitov's
study, but this peripheral argument is not convincing.   Anatomical and
histological investigations may provide some information on this point.
It is of interest to note that when the data in the present study was
analysed controlling for 'normal' acuity as in McGuinness's study, there
was still no significant difference between the two means (males 6.6:
females 6.8).

The lack of consistency between the findings of the three studies
points to the need for much more research into this problem using carefully

standardised apparatus and methodology.   One possible explanation for
the differences may relate to the visual angle employed in each instance.
Rod performance is known to be minimal near the foveal region and
maximal at about 20° of the visual angle on the temporal side
It may be that the visual angle employed is a critical factor in
predicting differences in performance between the sexes in the dark adapted
eye.   Hormonal levels in the female group might also be a variable which
must be controlled.   This is discussed more fully in a later section,
but if the sexes are shown to differ at absolute scotopic threshold it
would provide a plausible biological argument relating either to chemical
changes in the function of the rods, or in the higher centres of the brain.

2. Glare: The apparently large difference between the means obtained for
the two sexes might suggest that males are more sensitive to glare than
females.   In fact, however, no significant difference between the mean
performance of the two sexes was revealed by statistical analysis, due
to the vast range of individual performance in both groups.   In the
only other study known to this author relating to differences between
the sexes in their subjective reaction to light intensity, McGuinness
(1975) reported a significant difference, with males being more affected
by light.   In her study, however, subjects were asked merely to set levels
of light at which they felt they could look 'indefinitely', making the
task even more subjective and open to different interpretations than
asking the subjects to react to a 'just uncomfortable' level of intensity.

McGuinness's findings might have led one to expect an even greater
difference between the sexes at the 'just uncomfortable' level, if one
considers the power function, reported by Stevens (1961) to operate
across all modes as intensity is increased.   McGuinness reports a sex
difference at the lowest end of the intensity range - a level which was
assessed as continuously comfortable.   Thus when levels are increased
beyond this point, one would expect the disparity to become more marked,
as their power slopes begin to deviate.   That this has not been
demonstrated indicates that differences in methodology have again
revealed an inconsistency in the findings, re-emphasising the need for
more research of a standardised nature.

As for scotopic threshold, significant differences were obtained
between the males and one sub-group of the normally menstruating females,
the males being more sensitive.   This would indicate the possibility

of hormonal level effects, and provide some support for McGuinness's findings that males are more sensitive to light intensity. Again this will be discussed at greater length in a later section, but the possibility that hormonal levels effect either the chemical changes in the cones in their reaction to brightness, or the cortical centres, cannot be dismissed. As judgement of brightness and visual acuity are both functions of the cone system, a relationship between the two parameters might have been expected. Since this was not found, it could suggest that two separate mechanisms are involved and provides support for the suggestion of cortical centre involvement. Stone and Groves (1968) lend support to this suggestion. In their study of discomfort, glare, and visual performance they conclude that retinal receptors are unlikely to enter into discomfort glare response mechanisms.

3. Discrimination - Visual Acuity: The finding that males have better acuity than females on the tests described in Chapter 3 is in accord with the study by Roberts (1964), who found in a sample of 6.672 subjects a similar trend to that observed here. Men were far less likely to be found at the poor end of the scale and predominated at the opposite end of the scale (see Figure 10, Chapter 4). This effect increased with age. It is well known that there are many different types of acuity and that the tests used in this study may not be the best measure to employ. However, these results are in line with other acuity measures (Burg and Hulbert, 1961; Burg, 1966), where men were found to be superior to women in both static and dynamic tests to various types of target.

The superiority of performance by males in visual acuity tests is somewhat difficult to explain - especially since the findings of studies on infants and children show no difference between the sexes in acuity (Fagan, 1972; Skoff and Pollack, 1969). The neurological and physiological determinants of acuity have never been fully described, but it would appear explanations involving pupil diameter may be discarded (Rubin and Wall, 1969), as may those relating to eye movements (Gilbert and Fender, 1969). In subjects with gross acuity deficiencies, abnormalities of the lens or lens muscle may provide an adequate explanation, but this appears less plausible when assessing finer distinctions between subjects with superior to normal vision. As an explanation of the difference between the sexes, which do not appear until about the mid-teens, it might imply some differential ageing effect to lens control. The fact that differences between the sexes largely disappear when

corrective lenses are worn (Wilson, 1977) certainly suggests that the
lens is one important factor.   Investigative studies into the precise
differences between the sexes with regard to lens and focal length, eye
movement, pupil size and angle of presentation may provide useful information
about peripheral mechanisms.

    That the lens is unlikely to be the only factor involved is suggested
by the numerical domination of the males in the superior to normal range,
and the skew in opposite directions of the two groups.   A peripheral
explanation is less convincing here.   Lesions of the occipital centre,
particularly the foveal arinate region, are known to impair visual acuity,
and higher centre involvement cannot be discarded.   The late appearance
of sex differences suggest either that learning or maturation may be
involved, or that hormonal changes are involved.

    That visual acuity could be affected by environmental factors and
that the sex difference relates in some way to cultural processes poses
the problem of what initiated the environmental effect, and what form
does it take.   Emphasis on the visual systems might be expected to cause
deterioration rather than improvement.   As an example of the way in which
cultural processes might affect visual acuity, McGuinness (1975) has
suggested that females may become more myopic because they spend more
time reading (relating to their greater verbal ability), while male
acuity may become more efficient because of their greater interest in
physical activity and sport.   The fact that in this study the subjects were
all specialist students of physical education, with similar interests and
educational attainment detracts from the plausibility of such an argument,
however.

    A biological explanation in terms of the developmental lag hypothesis
could explain the later appearance of superior visual acuity in males, but
it does not adequately explain the fact that no differences between the
sexes are observable until the post-pubertal stage, and other biological
explanations are at least as valid.   The theory proposed by Andrew (1972),
which was previously described in connection with visual-spatial ability,
is a possible one.   Andrew suggests that testosterone operates in vision
by stimulating foveal mechanisms and suppressing peripheral vision.   This
could explain the late appearance of the superior ability in males without
the need to postulate cross-over effects due to developmental lag.
Unfortunately, however, Andrew's suggestion appears to be demonstrable only

in chickens. One could perhaps test its validity in humans by assaying the levels of circulating testosterone in males who are at the extreme ends of the visual acuity scale.

Thus it seems possible that superior visual acuity is primarily dependent upon biological effects, although environmental effects cannot be entirely ruled out. The findings offer no proof of any hemisphere dominance theory, as acuity is dependent upon the cone system, sub-cortical and occipital regions only, and it is possible that a number of the explanations outlined may be operating concurrently.

The Menstrual Cycle

In the visual modality Diamond et al. (1972) using three groups of four subjects in the same way as that described for Baker and Weiler's study (1977), demonstrated that sensitivity, measured by the ability to detect a patch of light in a slightly less illuminated background was greatest at mid-cycle in normally menstruating females, and remained high until it declined abruptly at the onset of menstruation. Males, and females taking an oral contraceptive, did not display the same cyclical fluctuations and were more sensitive visually than the normally menstruating group.

Although Diamond et al's study was not a test of absolute threshold, the results can be compared with those obtained for dark adaptation in this study. Again the subjects were tested on only one occasion, but the results are remarkably consistent with, and provide support for, the findings of Diamond et al. Females in the pre-ovulation phase failed to obtain the same adaptation level as that attained by the other two groups, and were consistently slower in their dark adaptation rate for each aperture. Similarly the pre-ovulation group were significantly less sensitive to glare than the other two groups. No significant differences were obtained between the three sub-groups on any of the other visual tests.

Comparison of the data obtained for each sub-group with that of the males in both dark adaptation and glare again provides some interesting information. Whilst no significant differences were revealed between males and the whole female group in previous analyses, significant differences were found between females in the pre-ovulation group and

the males in both tests, with males being more sensitive in both instances. This provides support for the findings of Ippolitov (1972) in visual threshold, as well as conforming to the findings of Diamond et al. Two explanations for this might be proposed. The first relates to the possibility that cyclical hormonal fluctuations in females affect the higher centres (in much the same way as proposed for the auditory modality, but with different effects), making them less sensitive to visual stimuli in the pre-ovulatory phase. The second could be more peripheral, in that the changes might effect rod sensitivity (itself a chemical process). Neither of these suggestions is mutually exclusive and each may work in conjunction with the other.

On the basis of the results both in this study and in those discussed in this section, the acceptance of a purely environmental explanation of sex differences in the parameters discussed becomes less and less tenable. The adaptive significance of the changes attributable to the menstrual cycle in the female has been described by Diamond et al, who concluded that they might result in a higher incidence of coitus at ovulation, since sensitivity to arousing stimuli would be greater but pain sensitivity reduced. There is insufficient evidence to properly assess this theory but it is an attractiv one, and no alternative has been proposed. It is, however, quite possible that the changes are merely incidental to other functions of these hormones, and a physiological explanation seems equally plausible. Sex differences in several senses have been discussed. The circulating levels of sex hormones, affect the functioning of the sensory nervous system. The location within the system and the mechanisms by which they are effective are yet to be found - although Tobias (1965) has suggested such possibilities as changed rates of transmission. Nor is it inconceivable that hormonal levels affect the tonic inhibitory role of the cortex or lower centres on the ascending sensory information.

These explanations are not mutually exclusive, but are potentially compatible explanations addressing themselves to different aspects of the situation. It must be emphasised that hormonal explanations cannot adequately resolve all sex differences. Some differences have been shown to exist in age groups where hormonal differences are unlikely to be markedly different.

Visual Correlations. The lack of stable correlations between performances
on tests in the visual modality in other studies has already been noted
(Ippolitov, 1972; Nebylitsyn and Gray, 1972; Strelau, 1972; McGuinness,
1975). The data presented here provides a similar lack of consistent
relationships between the visual parameters tested, with the exception of
visual acuity and dark adaptation and between the rate of adaptation and
sensitivity to glare intensity, for both sexes. Relationships between
other visual parameters were not consistent for both sexes.

The relationship between visual acuity and dark adaptation threshold
was unexpected, since Rubin and Walls (1969) maintain that laboratory
investigations have never established a relationship between visual acuity
and other visual parameters. Furthermore, the fact that visual acuity
is a function of photopic vision, whilst threshold is a scotopic process
would make it seem unlikely that any relationship should exist.
Nevertheless McGuinness (1975) using a different methodology also reports
a correlation between these two parameters, and points out that the
absence of previous findings regarding this relationship could be explained
by the fact that subjects participating in a dark adaptation experiment
are usually screened for acuity at the outset of the experiment.

This result gives rise to two possible suggestions. The first is
that acuity and dark adaptation threshold are related, and the unaided
myopic individual will have poorer dark adaptation than someone with normal
vision. It could, however, be that when myopic subjects have corrected
to normal vision by the use of an artificial lens, this relationship may
disappear. This last suggestion may be resolved by examining the dark
adaptation curve of subjects with better than normal eyesight. If such
subjects have superior dark adaptation it would suggest that the first
argument is the relevant one. In fact, however, statistical analysis
of those subjects who scored 6/5 on the visual acuity test, compared to
other subjects, revealed no significant difference in the rate and level
of dark adaptation, suggesting that the second argument is more appropriate.

The relationship between the initial rate of dark adaptation and the
reaction to glare intensity can perhaps be attributed to the nature of the
glare test, in which subjects who were in a dark adapted state were
presented with a steadily increasing amount of glare source. This could
be interpreted as a test of the rate at which the individual adapts to
light from the dark adapted state. This being so, the relationship would

appear to be a positive one (p≯0.05) between the rate of dark adaptation
and the rate of light adaptation. This relationship was not anticipated,
since the peripheral mechanisms involved in photopic and scotopic visual
processes differ, and suggests that there is some involvement of central
control mechanisms in determining the rate at which an individual adapts
to different levels of light.

The relationship established for the total group (and for females)
between the level of dark adaptation (used as a test of visual threshold)
and the subjective reaction to glare intensity (p>0.05) lends some support
to the finding for the auditory modality that the parameters are related
(see also Hood, 1968). Once again, however, the relationship does not
appear to hold for the group of male subjects. However, the findings of a
study by Silverman et al. (1969) may provide a pertinent explanation of
this phenomenon. In their study of the relationship between intensity and
threshold in visual and in kinaesthetic performance, Silverman and his
co-workers divided a group of males and a group of females into 'augmenters'
and 'reducers'-a classification first introduced by Petri (1967). For
both the male and female groups a significant positive correlation was
obtained between the two parameters, which was higher for the female group.
Males with low sensory threshold scores, however, tended to reduce stimulus
intensity - a tendency not found in the females. If males with a high
threshold tend to augment stimulus intensity while males with a low
threshold reduce it, this would mask any overall correlations between
performance in the two tests (dark adaptation and glare), and could have
some bearing on the findings of this study. The lack of a significant
correlation for the males, however, together with the low correlation
obtained for the females does not allow the establishment of this relationship
to be proposed as conclusive.

SUMMARY

In summary, then, the findings for the visual modality give rise to
fewer significant differences between the sexes than were evident in the
auditory mode. For threshold (as determined by adaptometry) there were no
significant differences between the sexes in either the time taken to
adapt to particular levels of darkness or the final aperture attained (except
when the females were divided into the three menstrual cycle sub-groups).
In their subjective reaction to intensity, too, measured using a glare
test, males and females do not differ significantly, unless the hormonal
fluctuations of the menstrual cycle are taken into account. What is

apparent, however, in both these parameters is that individual differences between subjects are considerable.

The data obtained for visual acuity (discrimination) does show a significant difference in favour of the males ($p > 0.01$) and this is in accordance with earlier studies (Roberts, 1964; Burg and Hulbert, 1961; McGuinness, 1975). This difference is largely due to more females than males scoring at the high end of the scale, with many more males than females attaining a score of 6/5.

When the female group were sub-divided into categories according to their stage in the menstrual cycle when tested, the reports supported those obtained by Diamond et al. (1972), who noted a lower visual sensitivity for females in the pre-ovulation phase. There was also a significant difference obtained between females in this sub-group and males in their subjective reaction to glare with the males being more sensitive ($p > 0.05$). Again the results suggest that hormonal levels are implicated in differences in performance between the sexes.

Intra-modal correlational analysis provides more statistically significant correlations than for the auditory modality. In the main, however, the data suggests that visual functions are not related in any stable, consistent manner. Thus in both the auditory and visual modalities correlational analysis provides little evidence of some qualitative unity to within mode performance. It is appropriate at this stage to examine whether a relationship exists between modalities in related tasks - for example performance at threshold, and for this reason we turn now to a consideration of cross-modal correlations.

CROSS - MODALITY CORRELATIONS

Within mode correlations in both the auditory and visual modalities have failed to establish significant consistent relationships between the parameters investigated in this study. This would lead one to predict that cross-modal relationships are also unlikely, a prediction supported by Strelau (1972). His review of the data on visual and auditory thresholds indicates that no consistent relationship is to be found, and he concludes that a unitary property of the nervous system for any given individual is difficult to demonstrate, with individuals differing, for example, in mode of response, reaction to stimulus intensity, and the relationship of voluntary to involuntary speed of output. A similar argument is presented by McGuinness (1975).

TABLE 41: Correlations Between Auditory and Visual Threshold

	125	250	500	1000	2000	3000	4000	6000	8000	10000	12000
MALES	.11	.05	-.15	-.02	-.14	.11	.02	-.06	-.12	.06	-.14
FEMALES	.23*	.24*	.11	.19	-.11	-.01	.12	.18	.28*	.17	-.10
TOTAL	.14	.10	-.03	.09	-.13	-.05	.01	-.01	.02	.08	-.14

* Significant p > 0.05.

CORRELATIONS

1.   Threshold: Visual and auditory absolute threshold showed no
consistent relationship for either sex, but some significant relationships
were found between visual threshold (the final aperture to which the
subject successfully adapted) and auditory threshold at some frequencies.
Correlations between these two parameters are presented in Table 41, as
are correlations between peripheral vision and auditory threshold.   Again
some significant relationships are found (usually negative) but no
consistent pattern emerges.

2.   Just Uncomfortable Intensity Levels: The relationship between
subjective reactions to auditory and visual stimulus intensity are
presented in Table 42.   The correlations obtained for both the females
and the total sample indicate a clear, consistent, positive and significant
relationship between the two modalities, but this same relationship does not
hold for the males, except in one frequency.   It does seem possible to
argue from these findings, however, that the perception of intensity
changes is a higher level phenomenon unrelated to specific modalities,
and possibly independent of sensitivity at threshold.   This argument has
been suggested in part, by McGuinness (1975), on the basis of similar
findings, and will be discussed later.

TABLE 42.   Correlations for Visual and Auditory Just Uncomfortable
Intensity Levels

GROUP	250	500	1000	2000	3000	4000	6000	8000
MALES	.02	.06	.13	.16	.16	.18	.23*	.16
FEMALES	.29+	.31+	.40+	.33+	.30+	.39+	.27+	.26*
TOTAL	.20+	.16*	.22+	.15*	.20+	.25+	.21+	.20+

significant $p > 0.05$ + significant $p > 0.01$

3.   DISCRIMINATION.   No consistent relationship was discernible
between the test of visual discrimination (visual acuity) and pitch
discrimination for males but the relationship between visual acuity
and pitch for females was significant $(p > 0.05)$.   Correlations between
these parameters are presented in Table 43 (Spearman's rho).

TABLE 43.   Correlations Between Auditory and Visual Discrimination.

GROUP	ACUITY (rho)
MALES	.06
FEMALES	.23*
TOTAL	.15*

* significant p > 0.05.

DISCUSSION

It is suggested in Nebylitsyn and Gray (1972) that each individual has certain distinctive properties of the nervous system which operate across all modalities, thus rendering one individual considerably more sensitive at absolute threshold for all modalities, another individual more sensitive to intensity tolerance over every modality, and so on. Soviet psychologists, in particular, refer to the Pavlovian concept of the strength of the nervous system (Borisova, 1972; Golubeva, 1972; Ippolitov, 1972; Teplov, 1972), which is characterised (amongst other factors) by "the magnitude of absolute visual and auditory sensitivity" (Teplov, 1963), determined by the measurement of thresholds which are, as a rule, higher in subjects with a strong nervous system and lower in those with a weak nervous system (Golubeva, 1972). This view is not supported, however, by the findings of Strelau (1972). In his review of the data on auditory and visual thresholds he indicates that no consistent relationship is to be found. The findings of this investigation endorse Strelau's view, and no significant, consistent relationship emerges between performance at threshold in the auditory and visual modalities in the tests used here.

The Russian studies allowed considerably longer than the thirty minute period allocated for dark adaptation in this investigation.   It would be surprising, however, if this made any major difference to the result obtained, since Wald (1961) suggests that only very small increments of adaptation are likely to be obtained beyond the thirty minute period. Moreover, correlations between the time taken to adapt to Aperture 16 (the first aperture) and the final aperture attained were significant and positive, indicating a high, positive relationship between the rate of adaptation and the final level of dark adaptation.   Furthermore,

correlations between performance at auditory threshold for different frequencies did not display as consistent and significant a correlation as might be expected (this is discussed later), indicating that sensitivity at auditory threshold may be a function of frequency. This must call into question the Soviet description of 'strong' and 'weak' nervous systems, and lends support to Strelau's conclusion that a unitary property of the nervous system for any given individual is difficult to demonstrate. Certainly cross-modal comparisons in all the parameters investigated in this study display a lack of consistent and significant relationships. Indeed, even within-mode correlations in both the auditory and visual modalities yield few relationships of this nature. Further consideration is given to this argument in the discussion of personality, later in this section, when it takes on even greater significance.

In one parameter, however, the findings do indicate a consistent and significant cross-modal relationship. The correlations obtained between the subjective reactions of individuals to loudness at all frequencies and to glare intensity for the total sample do attain a significance of $p > 0.01$ for all but two frequencies (500 Hz, 2,000 Hz), where the level of significance is $p > 0.05$. Similar findings have been reported by McGuinness (1975) and by Schechter and Buchsbaum (1973). This subjective reaction to intensity may more appropriately describe the 'strength' or 'weakness' of the nervous system, and provide some support for the Russian view, since it would appear that, as was stated in the previous chapter, the perception and tolerance of intensity is unrelated to specific modalities, and is an enduring property of the central nervous system of an individual. The ability of an individual to set consistent criteria for the acceptance of intensity levels in two modalities would appear to indicate the existence of a central intensity control mechanism, and that individual differences in intensity response do not relate specifically to sensensitivity in a particular modality. Interestingly, Schechter and Buchsbaum (1973) found that cross-modality intensity correlations appeared only under certain attentional conditions, and it would seem reasonable to suggest that the reticular formation is therefore implicated as part, at least, of the intensity control mechanism. Further support for the suggestion that such a mechanism exists comes from studies of individual response to pain induced by increasing the intensity of stimuli. Brown et al. (1973), for example, found correlations between response to cold and pressure intensity, and they state that responsiveness to pain, as

indicated by threshold, tolerance, and ratings of intensity, is not stimulus-specific, but can generalise across at least two kinds of pain-producing stimuli. Silverman et al. (1969) point out that a number of studies of individual differences is responsiveness to sensory stimulation have suggested a model of a central nervous system mechanism which controls stimulus intensity (Bucksbaum and Silverman, 1968; Petrie, 1967; Silverman, 1967). The modal, based in large part on the experimental work of Petrie and her colleagues (Petrie et al, 1963; Petrie, 1967) originally distinguished two unique patterns of response to sensory input. 'Augmenters' are individuals who amplify sensory stimulation, consequently tending to tolerate pain poorly and tolerate confinement and isolation well. 'Reducers', in contrast, attenuate sensory stimulation, tending to tolerate pain well but tolerate sensory deprivation situations poorly. Again, we shall return to this discussion at a later stage.

It would seem impossible at this stage to specify the precise nature and structure of the intensity control mechanism. However, an exciting possibility has been proposed by Pribram and McGuinness (1975). In their review of arousal and the control of attention, they postulate a loop involving the reticular formation of the brain stem, the hypothalamus, the amygdal , and the frontal lobes. They present evidence from studies on monkeys, primarily, and point out that ample evidence exists to suggest that arousal as a result of intensity changes is associated with the reticular formation and the hypothalamus. Evidence for the involvement of the amygdala and related frontal cortical structures stems from amygdalectomy and resection of the amygdala. Amygdalectomy results in failure of behavioural habituation and animals become tame, unresponsive to threat and non-aggressive. The evidence delineates two reciprocally acting circuits, one facilitatory and the other inhibitory, both converging on the hypothalamic structures related to arousal (Ursin and Kaada, 1960). This reciprocal innervation allows sensitive modulation of the arousal mechanism.

In essence the argument proposed by Pribram and McGuinness is as follows: studies relating brain function and the orienting reaction to sensory input have pointed to the presence of a system of neurons responding to the amount of input to them by maintaining or incrementing their activity. This core system of neurons extends from the spinal cord through the brainstem reticular formation, including hypothalamic sites,

and lies in close proximity to those responsible for the engenderment
of visceroautonomic responses. By way of its diffuse connections, this
system is responsible for the more ubiquitous 'arousal' response recorded
throughout the brain concomitant with orienting. Forebrain control over
this corebrain arousal system is exerted by reciprocal facilitatory and
inhibitory circuits centred on the amygdala. These circuits control
the onset and duration of neural arousal much as they control the onset
and duration of visceroautonomic and appetitive responses (see Pribram
and McGuinness, 1975 for review). More information would appear to be
necessary before this suggestion can be adequately assessed, but it would
seem to have considerable plausibility as an intensity control mechanism,
and might be implicated in the individual's subjective reaction to just
uncomfortable loudness and glare.

For discrimination in the two modalities, a low relationship ($p > 0.05$)
was found for females and the total group between pitch discrimination
and visual acuity, which might have given rise to a similar type of
proposal concerning discriminative ability. There is, however, no such
relationship between colour discrimination and the other discriminative
tasks (i.e. Rowe, 1978) and a conservative consideration of the evidence
leads one to the conclusion that no consistent, positive relationship in
discriminative ability has been established.

General Conclusions. Examination of the correlational data in both the
auditory and visual modalities reveals that, in general, relationships
between the parameters are low and display a marked lack of consistency.
It is difficult, therefore, to argue in a conclusive manner that hearing
and vision are unitary phenomena, in which the performance of different
tasks are closely related. Some relationships have been established and
some arguments have been proposed as explanations where inconsistencies
are evident. It may be more profitable, however, to regard the two
modalities as being comprised of separate and qualitatively different
sensitivities, rather than thinking in terms of an overall auditory or
visual 'stimulus hunger' as proposed by Garai and Scheinfeld (1968) for
females and males respectively.

PERSONALITY
The concept of strength of the nervous system referred to earlier
has some relevances for the discussion of personality. Teplov and

Nebylitsyn (1969) argue that individual differences in behaviour are
determined by certain properties of the nervous system, and it would
seem that the Pavlovian notion of "strong" and "weak" nervous systems,
which has formed the basis for most of Teplov's experimental work, bears a
striking similarity to the notions of extraverted and introverted
personality types as they emerge from the work of Western psychologists
such as Eysenck. The "weak" personality type appears to resemble the
introvert, the "strong" personality type the extravert. Even if it is
admitted that similarity does not imply identity, it is certainly striking
that two quite independent approaches should issue in such closely
related concepts (Eysenck, 1967).

This similarity becomes even more apparent when personality types
are considered in terms of physiological and neurological concepts. Gray
(1964) has translated the concepts used by Pavlov and Taplov into the
language of modern neurophysiology, and has shown that different degrees
of arousal of the reticular formation can mediate all or most of the
experimentally ascertained differences between "weak" and "strong" nervous
systems. In a similar manner, Eysenck (1967) has suggested a close
relationship between reticular formation arousal thresholds and introversion-
extraversion. According to these theories, low thresholds of the
ascending reticular activating system would be characteristic of the
"weak" nervous system and the introvert, high thresholds of the "strong"
nervous system and the extravert. Again, the synchronizing part of the
reticular formation exerts an inhibitory influence on cortical activity,
and it may be supposed that low thresholds of this system characterise the
extravert and the "strong" nervous system. Unfortunately little direct
evidence is available relating to these theories.

The Pavlovian concepts have already been challenged by the
correlational data discussed in the previous section. It is therefore,
pertinent to subject the Eysenckian view of personality to the same
scrutiny. Eysenck and Levy (1972) suggest that sensitivity in all
modalities is related to personality, with introverts more sensitive than
extraverts, and produce some supportive evidence. However, investigative
studies relating personality differences to sensory or perceptual tasks provide
no consistent evidence for such a claim (see Nebylitsyn and Gray, 1972),
and it has been suggested that sex differences appear to be greater than
those associated with personality factors.

The hypothesis of Eysenck (1967) that extraverts possess a strong

nervous system with rapidly generated central inhibition has been
challenged by Coles et al. (1971) on the grounds that it is too general
to account for the differing reactions to various parameters of stimuli,
but it may apply at a more specific level, for example, where intensity
is a significant parameter in setting initial levels of arousal. However,
in the many studies in which stimulus intensity has been increased to
the levels of pain threshold and pain tolerance, correlations between
pain responsivity measures and the personality variables investigated
here (extraversion-introversion; neuroticism-stability) have shown no
consistent pattern. Although a few studies report significant correlations
between one or more of the pain responsivity measures and one or more of
the personality variables (Davidson and McDougall, 1969b; Lynn and
Eysenck, 1961; Martin and Inglis, 1965; Poser, 1960; Schalling, 1971),
these correlations are small in magnitude and display some inconsistencies
dependent upon the type of stimulus used. Other studies report non-
significant results (Davidson and McDougall, 1969a; Brown et al, 1973;
Mumford et al, 1973) and Adler and Lomazzi (1973), who used measures
of 'perceptual style' (field dependence/independence) rather than the
personality traits cited earlier, similarly indicate a lack of significant,
close correlations between these measures and pain tolerance.

The correlational data obtained in this investigation demonstrate no
consistant significant relationship between personality variables and
sensory sensitivity, although in both modalities some significant correlations
were obtained. It is perhaps surprising, however, that sex differences
were discernible in both modalities, with personality being related to
sensory sensitivity only at levels above absolute threshold, especially
where subjective factors were more apparent. Thus in the auditory
modality, the data indicated that female extraverts tolerated higher
levels of loudness than female introverts, but no such relationship was
found for males. Other studies have reported similar findings (Stephens,
1971; Stephens and Anderson 1971; McGuinness, 1975) with the
relationship being more consistent for females than males. In the visual
experiments the most significant relationship was between glare intensity
and personality for females - but in this instance the relationship indicates
that stable (not extravert) females tolerate higher levels of glare than
neurotic females. Again no significant relationship was established
for males. Whilst both these results are to some extent consistent with
Eysenck's theoretical model, that the relationship occurs only in females
poses some problems for a general theory of personality effects and
emphasises the need to consider the two sexes separately in studies of

individual differences.

Thus the personality data provided in this study in relation to auditory and visual sensitivity have presented contradictory and inconsistent results which challenge the more general Eysenckian theory that reaction to intensity is a general property of the nervous system across all modalities, which relates to personality types.   It is accepted that the subjects used in this study were predominantly extravert, and different results might be obtained if one were to test groups at the extremes of the introversion-extraversion and neuroticism-stability continua. Nevertheless, when considered in relation to the other studies cited here, the results do suggest that current theories of personality provide an oversimplified model which do not fully account for the experimental data. It is to be hoped that this data might provide a challenge to experimenters to try to assess what specific characteristics in personality produce a consistent reaction to sensory processes.

The sex differences revealed in the correlation of personality traits to sensitivity in specific sensory processes in the auditory and visual modalities suggest either that these traits are entirely different for men and women or that questions must be raised concerning the validity of using the same personality questionnaires for both sexes.   The Eysenck Personality Inventory (Eysenck and Eysenck, 1964) has allegedly eliminated all items with a strong sex bias.   The Eysencks' standardisation of their scale, however, has used means and standard deviations only, and there may well be a hidden sex difference in the way in which males and females respond to the questionnaires.   It would appear, then, that the definition of personality traits by responses to questionnaire items must be determined separately for each sex.   A question could be answered in certain ways for a number of complex (subconscious) reasons;   either because it is inherently correct due to temperament, or because of a conditioned attitude to specific parental influences, or because of socially acceptable or unnnacceptable connotations of the question for a particular sex.   Until questionnaire items properly assessing men and women are designed, it would seem impossible to determine what constitutes extraversion, neuroticism or any other personality trait in the two sexes.

CONCLUSION

In this, and the previous, chapter data has been presented relating to the performance of males and females in a number of auditory and visual

tests.   The differences observed between the sexes in the performance
of these tasks have been discussed with particular reference to existing
theories of sex differences.

The investigation has been further extended by controlling for
personality factors which could obscure sex differences.   The results
obtained pose some problems for current personality theory, particularly
in relation to the construction of personality questionnaires and the
response they elicit from men and women.   The incorporation of extensive
correlational analyses also has some bearing on personality theory, and
provides scant support for the existence of some qualitative unity to
within mode performance, or cross-modality relationships in such parameters
as performance at threshold.

In Chapter 2 it was suggested that there could be a relationship
between performance in sensory sensitivity and basic perceptual parameters
and the development of sex differences in cognitive abilities.   Before
this suggestion can be fully evaluated, and stemming from the establishment
in this study of sex differences in auditory and visual parameters, it is
necessary to undertake a further phase of investigation.   The next chapter
outlines the nature of this investigation and the results obtained.

CHAPTER 6

THE SECOND PHASE EXPERIMENTS

INTRODUCTION

In Chapter 2 mention was made of the suggestion by Garai and Scheinfeld (1968) that the two sexes begin life with different perceptual biases, related to sensory sensitivity in the auditory and visual modalities, which affect development and may provide an explanation, at least in part, for sex differences in aptitudes detected later in life. In this thesis evidence has been presented for differences in sensory and basic perceptual abilities that are present in a group of young adults, after the developmental process is complete and before noticeable ageing effects occur. This evidence, when related to other available findings on sex differences in earlier age groups, demonstrates that at least in some parameters (primarily in the auditory modality) these effects are consistent over time, and may contribute towards an explanation for differences in behaviour discernible from early infancy onwards (see Chapter 2).

It was also suggested in Chapter 2 that if a significant relationship could be established between performance in the auditory and visual modalities and performance in those cognitive abilities in which the sexes are reported to differ, this would provide further experimental support for Garai and Scheinfeld's proposal.

Accordingly, having established that differences between the sexes do exist in the performance of visual and auditory tasks at the sensory or basic perceptual levels, the Bennett Differential Aptitude Tests (Bennett et al, 1966) were administered to those members of the original group of subjects (see Chapter 3) who were still at the college after the administration of the first phase experiments and the analysis of the results had been completed. The group consisted of 40 subjects in all, 20 of whom were males and 20 were females.

The Differential Aptitude Tests (DAT); Forms L and M.

The Differential Aptitude Tests (DAT) were originally developed in 1947 to provide an integrated, scientific, and well-standardised procedure for measuring the abilities of American junior and senior high school

students for purposes of educational and vocational guidance. They were also used in the educational and vocational counselling of young adults out of school and in the selection of employees. In 1963 Bennett and his co-workers (1966) updated the tests to meet new demands of large and small-scale guidance programmes. Minor revisions in the format of the tests were effected to provide easier administration and scoring, and there was a complete restandardisation on a nationwide sample of more than fifty thousand cases. The tests thus provide an integrated battery of tests of different abilities or aptitudes for which a well-standardised set of norms exist (albeit for an American population) for the age group tested in this study. Each test may also be regarded as an independent test and each of the abilities to be measured should be tested separately. Instructions for the administration and scoring of the tests are standardised and are explicitly set down in the test manual (Bennett et al, 1966; p p. 2.1 - 2.13).

There are eight abilities tested in the battery of Differential Aptitude Tests. These are as follows:

1. Verbal Reasoning: a measure of ability to understand concepts framed in words. The test is aimed at the evaluation of the student's ability to abstract or generalise and to think constructively, rather than at simple fluency or recognition.

2. Numerical Ability: designed to test understanding of numerical relationships and facility in handling numerical concepts.

3. Abstract Reasoning: this is intended as a non-verbal measure of the student's reasoning ability. The series presented in each problem requires the perception of an operating principle in changing diagrams.

4. Clerical Speed and Accuracy: the test is intended to measure speed of response in a simple perceptual task. The student must first select the combination which is marked in the test booklet, then bear it in mind while seeking the same combination in a group of similar combinations on a separate answer sheet, and, having found the identical combination, underline it. The objective of the test is to measure speed of perception, momentary retention, and speed of response.

5.   Mechanical Reasoning: the test attempts to measure the facility with which an individual learns the principles of operation and repair of complex devices.   Each item consists of a pictorially presented mechanical situation together with a simply worded question. Care has been taken to present items in terms of simple, frequently encountered mechanisms that do not resemble textbook illustrations or require special knowledge.   The score is affected by the previous experience of the subject but not, according to the author, to a degree that introduces serious difficulties in interpretation.

6.   Space Relations: a measure of ability to deal with concrete materials through visualisation.   The items require mental manipulation of objects in three-dimensional space.   In both this and the Abstract Reasoning test the patterns and other drawings are large and clear, and the authors claim that no premium is placed on visual discrimination.

7.   Language Usage - I: Spelling: measures the ability to spell words in common usage, and is dependent upon the student's previous experience.

8.   Language Usage - II: Grammar: this section is intended to measure the student's ability to distinguish between good and bad grammar, punctuation and word usage.

It will be noted from the list of abilities tested by the Differential Aptitude Test (DAT) that it provides a measure of all the cognitive abilities discussed in Chapter 2, in which sex difference in performance have been demonstrated or thought to exist.

The test was administered to the whole group in two sessions, on two consecutive days, in accordance with the general principles recommended in the test manual.   Each session lasted approximately two hours, starting at 10.30 a.m. on both days.   In the first session, students completed the test battery contained in Booklet I (Verbal Reasoning; Numerical Ability, Abstract Reasoning; Clerical Speed and Accuracy), and in the second session, the battery of tests contained in Booklet 2 was completed (Mechanical Reasoning; Space Relations, Language Usage -I: Spelling; Language Usage -II: Grammar).   The test took place in a well-lit, well-ventilated lecture room with no external distractions.

On completion of the test sessions, the answer papers were collected and scored by hand in accordance with the procedure outlined in the test manual.

RESULTS

The information obtained from the investigation described in the preceeding section was subjected to two types of statistical analysis. In the first instance a 't' test was applied to the data to determine whether or not significant differences exist in performance between the males and the females. Pearson's Product-Moment test of correlation was then applied to determine the existence of significant relationships between the auditory/visual parameters and the scores obtained in the various aptitude tests on the Bennett D.A.T. (Spearman's Rank Order test was used for the visual acuity data).

Table 44 shows the 't' values for age, and performance in auditory and visual parameters for the group tested on the Bennett D.A.T. (extrapolated from the original raw data obtained for the total sample). Comparison between the results shown in Table 44 and those presented for the same parameters in Chapter 4 for the total sample are, as one might anticipate, broadly similar, significant differences being shown in only one parameter, just uncomfortable loudness ($p > 0.02$). The figures for auditory threshold and for auditory intensity tolerance are presented for the best ear for one frequency only, namely 1,000 Hz. This frequency was chosen since the ear is reportedly most sensitive at frequencies in the region of 1,000 Hz (Licklider, 1951).

Sex differences in performance on the Bennett D.A.T. are presented in Table 45. The Mean Values obtained in each parameter for males and for females and the spread of scores are very close to the norms presented for young American males and females of a similar age group (Bennett et al. 1966).

It will be seen that significant differences between the scores of males and females were obtained in only two parameters: Space Relationships ($p > 0.05$) and Mechanical Reasoning ($p > 0.02$). In view of the differences reported in the literature reviewed in Chapter 2, one might have anticipated differences in a number of other parameters. However, it should be remembered that the group tested on this occasion were all students at a specialist college of Physical Education, who had been required to show

evidence of attainment of a relatively high educational standard as a prerequisite for entrance to the course. They had thus undergone similar formal educational training in numerical and verbal abilities and it is perhaps of note that the two parameters in which significant differences were obtained relate to abilities which are less formally presented within the school curriculum, and where it might be argued that opportunities for males to obtain some degree of training are better than those for females.

Correlation Coefficients: Before investigating the relationship between visual and auditory parameters and performance on the Bennett Differential Aptitudes Test, it is appropriate to examine the relationships which exist between the various parameters tested by the Bennett D.A.T. These are presented in Tables 46:1 (total sample), 46:2 (males) and 46:3 (females). As can be seen in all three Tables, there are high, significant relationships ($p > 0.01$) between all those tests which investigate aspects of language and language usage (Verbal Reasoning, Clerical Speed and Accuracy, Spelling and Grammar). Whilst one might have anticipated the existence of such relationships, it is reassuring for this study to have that existence confirmed by the data.

Slightly less predictable, perhaps, but in accord with the findings of other researchers (as presented in Chapter 2), is the existence of similar high relationships ($p > 0.01$) between Space Relations, Mechanical Reasoning and Numerical Ability, suggesting that these three parameters may similarly be grouped together. No significant relationships exist in this sample between the language/language usage parameters and the spatial/numerical tests. Thus the Bennett D.A.T. appears to test two unrelated groups of abilities.

The eighth parameter, Abstract Reasoning, shows a significant relationship with all the other parameters for the total sample (Table 46). Whilst correlating most highly with the language/language usage tests ($p > 0.01$), a significant relationship at the 0.05 level is also shown with the spatial/numerical parameters. However, this last relationship is not shown for either of the single sex groups.

TABLE 44 : 't' VALUES FOR AGE AND PERFORMANCE IN AUDITORY AND VISUAL PARAMETERS

PARAMETER	MALES		FEMALES		't' VALUE	LEVEL OF SIGNIFICANCE
	MEAN	S.D.	MEAN	S.D.		
Age	20.39	1.513	18.87	0.241	0.875	N.S.
Auditory Threshold	0.95	3.248	1.05	2.312	0.112	N.S.
Just Uncomfortable Loudness	90.60	8.327	83.70	8.950	2.525	Q02
Pitch	7.10	3.270	7.00	4.123	0.085	N.S.
Dark Adaptation (Aperture)	7.15	1.682	7.20	1.827	0.104	N.S.
Dark Adaptation/ Aperture 16	11.61	3.120	11.47	2.596	0.142	N.S.
Glare	30,155	19,733	33,665	19,252	0.569	N.S.

TABLE 45 : SEX DIFFERENCES IN PERFORMANCE: BENNETT D.A.T.

PARAMETER	MALES		FEMALES		't' VALUE	LEVEL OF SIGNIFICANCE
	MEAN	S.D	MEAN	S.D.		
Verbal Reasoning	34.65	7.40	33.85	7.60	0.337	N.S.
Clerical Speed/Accuracy	59.05	13.94	64.10	14.10	1.139	N.S.
Language :Spelling	74.35	15.75	81.40	12.41	1.572	N.S.
Language :Grammar	45.25	8.84	48.85	8.46	1.316	N.S.
Space Relationships	36.85	9.50	30.65	8.65	2.158	0.05
Mechanical Reasoning	47.25	10.86	37.75	10.47	2.816	0.02
Numerical Ability	27.90	6.33	25.45	6.59	1.201	N.S.
Abstract Reasoning	37.85	5.91	34.40	7.44	1.624	N.S.

TABLE 46.1 : MATRIX OF CORRELATION COEFFICIENTS - BENNETT D.A.T.

TOTAL SAMPLE

PARAMETER	Verbal Reas.	Clerical Sp/Ac	Spelling	Grammar	Space Rels.	Mechanical Ability	Numerical Ability	Abstract Reas.
Verbal Reasoning	1.000	0.851*	0.927*	0.798*	0.034	0.014	0.151	0.671*
Clerical Speed/Acc.		1,000	0.890*	0.858*	0.017	0.007	0.119	0.661*
Spelling			1.000	0.845*	-0.925	-0.123	0.112	0.549*
Grammar				1.000	-0.099	-0.060	0.099	0.621*
Space Relations					1,000	0.886*	0.757*	0.318+
Mechanical Reasoning						1.000	0.725*	0.346+
Numerical Ability							1,000	0.311+
Abstract Reasoning								1.000

* significant at 0.01 level (0.393), n= 40
+ significant at 0.05 level (0.304), n= 40

TABLE 46.2 : MATRIX OF CORRELATION COEFFICIENTS - BENNETTS D.A.T.

MALES

PARAMETER	Verbal Reas.	Clerical Sp/Ac	Spelling	Grammar	Space Rels.	Mechanical Ability	Numerical Ability	Abstract Reas.
Verbal Reasoning	1.000	0.819*	0.833*	0.846*	0.013	-0.044	0.190	0.719*
Clerical Speed/Ac		1.000	0.877*	0.860*	0.126	0.117	0.297	0.739*
Spelling			1.000	0.907*	0.079	-0.011	0.206	0.701*
Grammar				1.000	-0.030	-0.081	0.138	0.671*
Space Relations					1.000	0.897*	0.950*	0.176
Mechanical Reasoning						1.000	0.827*	0.113
Numerical Ability							1.000	0.194
Abstract Reasoning								1.000

* significant at 0.01 level (0.537), n= 20
+ significant at 0.05 level (0.423), n= 20

TABLE 46.3 :MATRIX OF CORRELATION COEFFICIENTS - BENNETT D.A.T.

FEMALES

PARAMETER	Verbal Reas.	Clerical Sp/Ac	Spelling	Grammar	Space Rels	Mechanical Ability	Numerical Ability	Abstract Reas.
Verbal Reasoning	1.000	0.931*	0.924*	0.816*	0.025	0.027	0.102	0.661*
Clerical Speed/Acc.		1.000	0.915*	0.846*	0.021	0.062	0.023	0.749*
Spelling			1.000	0.753*	0.016	-0.045	0.114	0.637*
Grammar				1.000	-0.016	0.162	0.152	0.761 +
Space Relations					1.000	0.853*	0.648*	0.345
Mechanical Reasoning						1.000	0.626*	0.415
Numerical Ability							1.000	0.194
Abstract Reasoning								1.000

* significant at 0.01 level (0.537), n= 20
+ significant at 0.05 level (0.423), n= 20

A.   Auditory parameters:

Tables 47, 48 and 49 shows the correlation coefficients obtained
for the total sample, males and females between each of the parameters
tested by the Bennett D.A.T. and three auditory parameters - auditory
threshold (1,000 Hz), just uncomfortable loudness (1,000 Hz) and pitch.
In Table [47], no consistent significant relationships were established
between threshold and the various aptitudes tested (although the
relationship for males between threshold and abstract reasoning was
significant at the 0.05 level).   Similarly in Table 49 , no significant
relationships are shown between any of the differential aptitudes parameters
and pitch for any of the three groups.

In Table 48, however, very high, significant negative correlations
($p > 0.01$) are shown between the reaction to uncomfortable loudness and
all the language/language usage parameters and abstract reasoning.
Thus the less tolerance an individual has of high noise levels, the higher
he or she scores on the Bennett D.A.T. in verbal reasoning, clerical
speed and accuracy, spelling, grammar and abstract reasoning.   Sensitivity
at threshold and ability to discriminate pitch, however, have no influence
on scores in these tests.

Thus for the one auditory parameter in which significant differences
exist between males and females, a consistent significant and high
relationship has been shown between sensitivity and performance in a
number of language tests.   Moreover, in both the auditory parameter
and the aptitude parameters the literature suggests that females are
superior (see Chapter 2).   The implications of this will be discussed
later.

B.   Visual parameters:

The correlation coefficients obtained between the Bennett D.A.T.
parameters and dark adaptation are shown on Table 50 (final aperture
attained in 30 minutes) and Table 51 (rate of adaptation to first
aperture).   In both tables the figures are low and inconsistent, with
only one significant relationship obtained - between dark adaptation and
numerical ability (Table 50) for females only ($p > 0.05$).   This
relationship is a negative one: that is to say that the greater the
threshold, the poorer the numerical ability of the individual concerned.
However, the fact that this relationship does not hold for the males or
the total sample presents some problems for the acceptance of the

TABLE 47 : CORRELATION COEFFICIENTS: BENNETT D.A.T. vs. ABSOLUTE
AUDITORY THRESHOLD (1,000 Hz)

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	0.210	0.413	-0.057
Clerical Speed/Accuracy	0.157	0.354	-0.112
Spelling	0.219	0.394	-0.088
Grammar	0.155	0.331	-0.099
Space Relations	0.021	0.110	-0.101
Mechanical Reasoning	-0.097	-0.029	-0.202
Numerical Ability	0.003	0.107	-0.129
Abstract Reasoning	0.198	0.469+	-0.045

* significant at 0.01 level

+ significant at 0.05 level

TABLE 48: CORRELATION COEFFICIENTS: BENNETT D.A.T. vs
UNCOMFORTABLE LOUDNESS (1,000 Hz)

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	-0.790 *	-0.868 *	-0.877 *
Clerical Speed/Accuracy	-0.809 *	-0.808 *	-0.820 *
Spelling	-0.848 *	-0.867 *	-0.906 *
Grammar	-0.719 *	-0.779 *	-0.634 *
Space Relations	0.071	-0.091	-0.004
Mechanical Reasoning	0.142	-0.055	-0.025
Numerical Ability	-0.066	-0.186	-0.111
Abstract Reasoning	-0.501 *	-0.820 *	-0.549 *

* significant at 0.01 level
+ significant at 0.05 level

TABLE 49: CORRELATION COEFFICIENTS: BENNETT D.A.T. vs. PITCH

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	-0.135	-0.106	-0.160
Clerical Speed/Accuracy	-0.141	-0.175	-0.166
Spelling	-0.255	-0.174	-0.361
Grammar	-0.119	-0.139	-0.105
Space Relations	-0.130	-0.041	-0.231
Mechanical Reasoning	-0.231	-0.278	-0.250
Numerical Ability	-0.253	-0.180	-0.322
Abstract Reasoning	-0.131	-0.134	-0.141

* significant at 0.01 level
+ significant at 0.05 level

TABLE 50: CORRELATION COEFFICIENTS: BENNETT D.A.T. vs. DARK ADAPTATION (APERTURE)

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	0.291	0.177	-0.151
Clerical Speed/Accuracy	0.039	0.164	-0.121
Spelling	0.079	0.185	-0.096
Grammar	-0.016	0.177	-0.283
Space Relations	-0.029	0.052	-0.132
Mechanical Reasoning	-0.162	-0.016	-0.379
Numerical Ability	-0.142	0.175	-0.528+
Abstract Reasoning	-0.170	-0.194	-0.160

* significant at 0.01 level

+ significant at 0.05 level

TABLE 51: CORRELATION COEFFICIENTS: BENNETT D.A.T. vs.
DARK ADAPTATION (RATE TO APERTURE 16)

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	-0.209	-0.250	-0.167
Clerical Speed/Accuracy	-0.227	-0.256	-0.195
Spelling	-0.138	-0.155	-0.108
Grammar	-0.196	-0.210	-0.178
Space Relations	-0.048	-0.158	-0.074
Mechanical Reasoning	-0.084	-0.142	-0.054
Numerical Ability	-0.107	-0.134	-0.092
Abstract Reasoning	-0.278	-0.421	-0.191

* significant at 0.01 level

+ significant at 0.05 level

TABLE 52 : CORRELATION COEFFICIENTS : BENNETT D.A.T. vs. GLARE

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	-0.069	-0.301	0.173
Clerical Speed/Accuracy	0.041	-0.147	0.202
Spelling	-0.068	-0.264	0.387
Grammar	-0.068	-0.264	0.387
Space Relations	0.006	-0.239	0.345
Mechanical Reasoning	0.039	-0.248	0.441+
Numerical Ability	-0.092	-0.459+	0.297
Abstract Reasoning	0.201	-0.001	0.414

* significant at 0.01 level

\+ significant at 0.05 level

TABLE 53 : CORRELATION COEFFICIENTS: BENNETT D.A.T. vs.
VISUAL ACUITY (SNELLEN)

PARAMETER	TOTAL SAMPLE	MALES	FEMALES
Verbal Reasoning	-0.001	0.123	-0.094
Clerical Speed/Accuracy	-0.061	0.012	-0.055
Spelling	-0.120	-0.023	-0.108
Grammar	-0.120	0.144	-0.008
Space Relations	0.305+	0.089	0.084
Mechanical Reasoning	0.286	0.005	0.012
Numerical Ability	0.301	0.062	0.238
Abstract Reasoning	0.146	-0.096	0.127

* significant at 0.01 level

+ significant at 0.05 level

validity of the relationship.

Table 52 shows the relationships obtained between the various aptitudes and glare. Again the results are inconsistent and low. No significant relationships are established for the total sample, but there is a significant negative relationship between numerical ability and glare for males (p> 0.05), and there is a significant positive relationship between mechanical reasoning and glare (p> 0.05) for females. Had these results been consistent across all three sample groups, they would have had greater significance for this study. However, further reference to these results will be made in a later discussion.

In Table 53. correlation coefficients (rho) are presented for visual acuity and the aptitudes. The only significant relationship established was for space relations for the total sample (p> 0.05). This is an interesting relationship in view of the significant difference between males and females reported in the previous chapter.

Overall, then, the correlations obtained between all the visual parameters and the aptitudes measured by the Bennett D.A.T. are inconsistent and low, with few exceptions. The implications of these results, and the other results presented in this chapter, are discussed in the next section.

DISCUSSION - SPECIAL ABILITIES

In Chapter 2 a number of reported differences between males and females in special abilities and intellectual functions were outlined. As Hutt (1972) points out:

> "The aptitudes which characterise males and females are well documented (Macoby, 1966; Tyler, 1965; Garai and Scheinfeld, 1968) and hence need little comment. In brief, females are superior in manual dexterity and accuracy, in perceptual speed and rote memory; males are superior in numerical and mechanical skills, in spatial perception and organisation".

This would appear to be supported by the data presented in Table 46. On the Bennett D.A.T. the mean scores for the males in this sample were superior to those obtained by the females in numerical ability (not statistically significant), mechanical reasoning (p> 0.02) and space relationship (p> 0.05). The female group on the other hand achieved

a higher mean score than the males for the clerical speed and accuracy test, but the difference was not statistically significant for this sample.   It is of interest to note, moreover, that the mean scores obtained by the male and female groups in this investigation were very close to those observed in the D.A.T. norms (Bennett et al. 1966) see Figures 12 - 16.

However, the belief that females are linguistically superior and hence score higher on most verbal tests is disputable. Garai and Scheinfeld list a number of studies investigating differences in performance between the sexes in verbal ability and conclude that in only very few of the verbal sub-tests are females unambiguously superior, and certainly overall, they do not obtain higher verbal IQ's.   What many tests do show, however, is that females are verbally fluent but in tests of verbal reasoning and comprehension they were lower than males, Tyler (1965) summarizes the position thus:

"Most of the available evidence seems to indicate .... that
it is in verbal fluency (what Thurstone has called W), rather
than in the grasp of verbal meanings (V) that females are superior
..... Comparisons of various groups of males and females on
various tests, however, has also made it fairly clear that girls
and women do not have larger vocabularies than boys and men do.)"

Inspection of the normative data of the Bennett D.A.T. is particularly pertinent, and makes the discussion between verbal reasoning and verbal execution very clear.   Below are given the mean norm scores on the D.A.T. (Form B) and their standard deviations for boys and girls at ages 13 and 18, for the three verbal tests, together with those obtained in this investigation, for comparison.

TABLE 54

Age	Sex	Verbal Reasoning		Spelling		Grammar	
		M	S.D.	M	S.D.	M	S.D.
13	Boys	15.8	7.9	25.9	21.9	20.2	13.7
	Girls	14.6	7.1	37.9	24.5	28.6	14.0
18	Boys	29.3	9.2	59.1	26.2	40.9	16.0
	Girls	25.2	9.4	72.1	20.6	45.8	14.4
This sample (18+)	Boys	34.7	7.4	74.4	15.8	45.3	8.8
	Girls	33.9	7.6	81.4	8.8	48.9	8.5
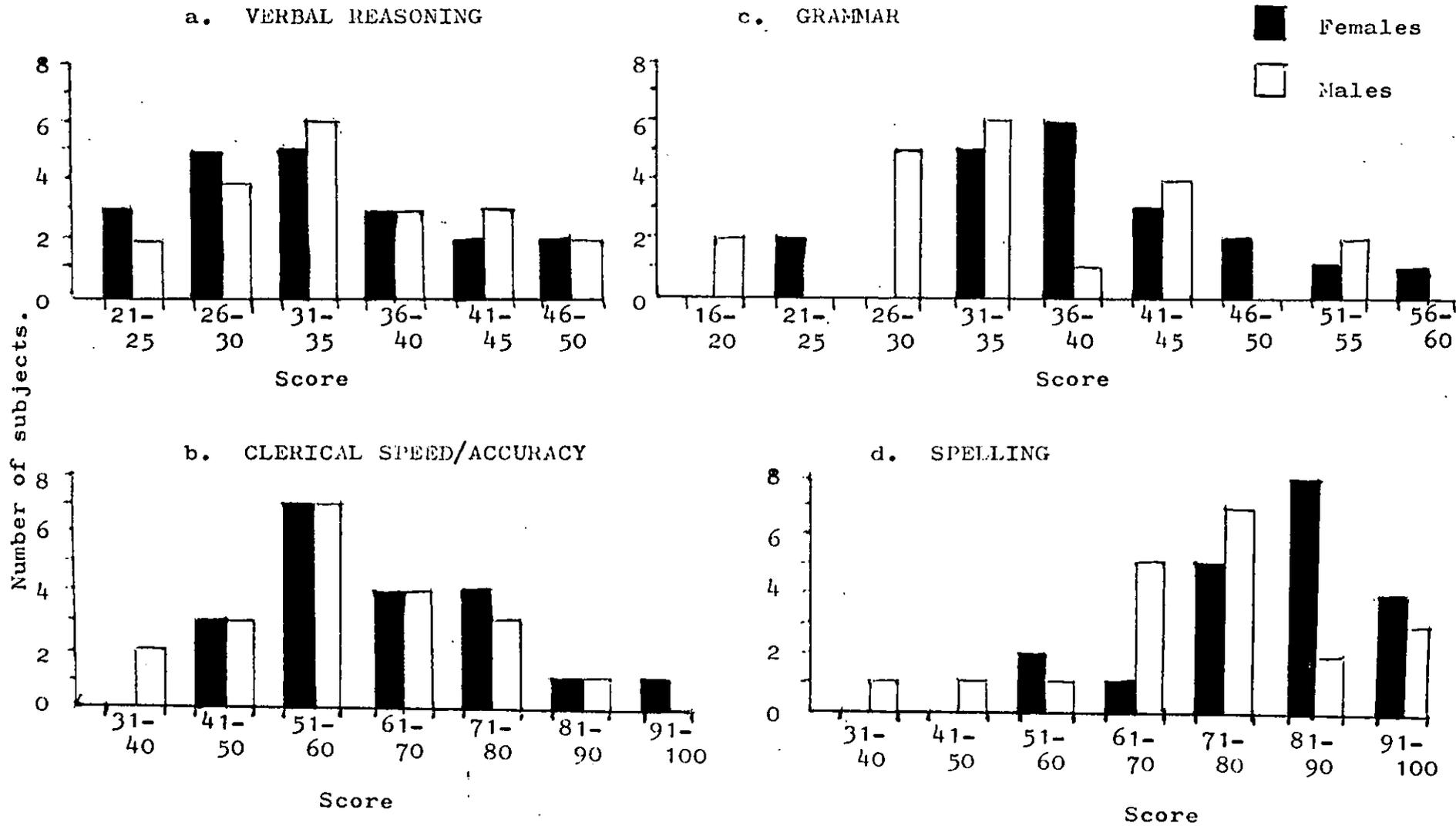
FIGURE 12 : Histogram of frequency distribution for males and females on Bennett DAT - Verbal Abilities.

a. NUMERICAL ABILITY
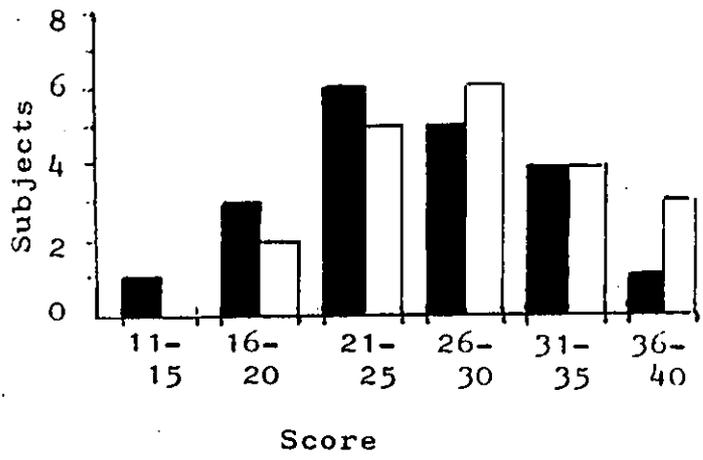
c. MECHANICAL REASONING
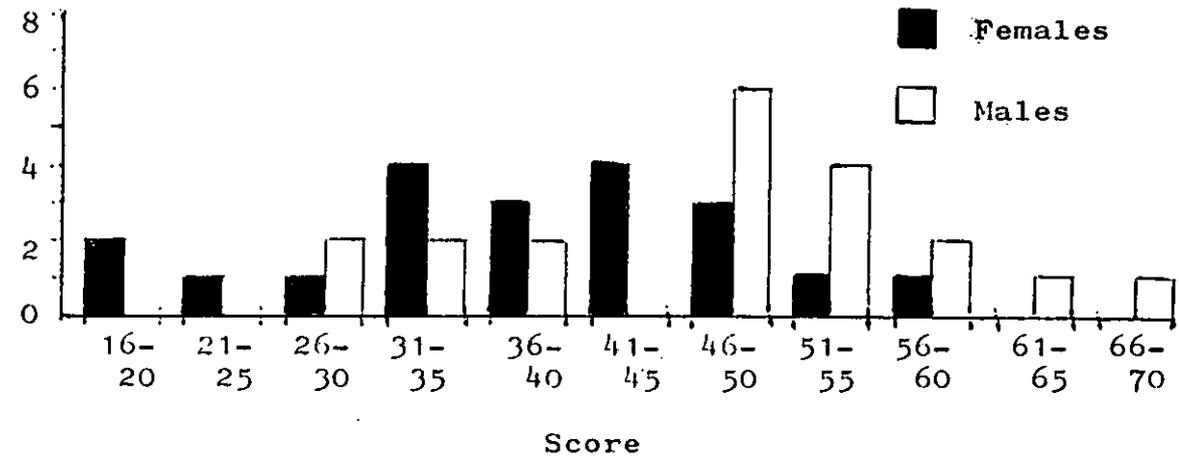
b. ABSTRACT REASONING
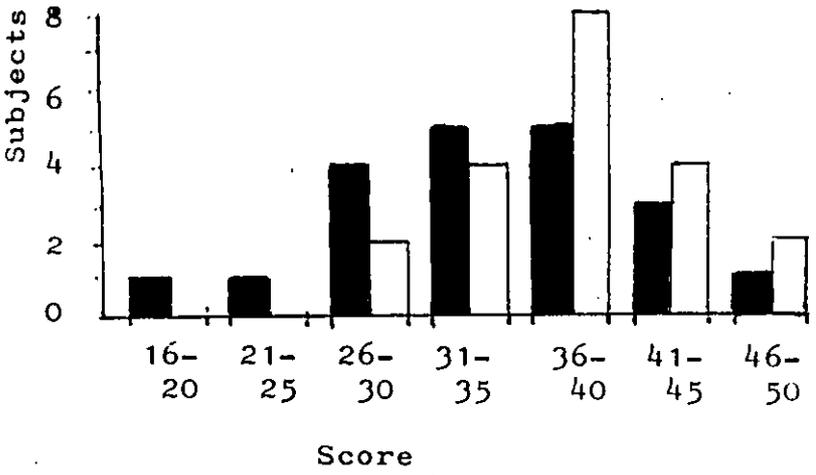
d. SPACE RELATIONS

FIGURE 13 : Histogram of frequency distribution for males and females on Bennett DAT - Non-verbal Abilities.
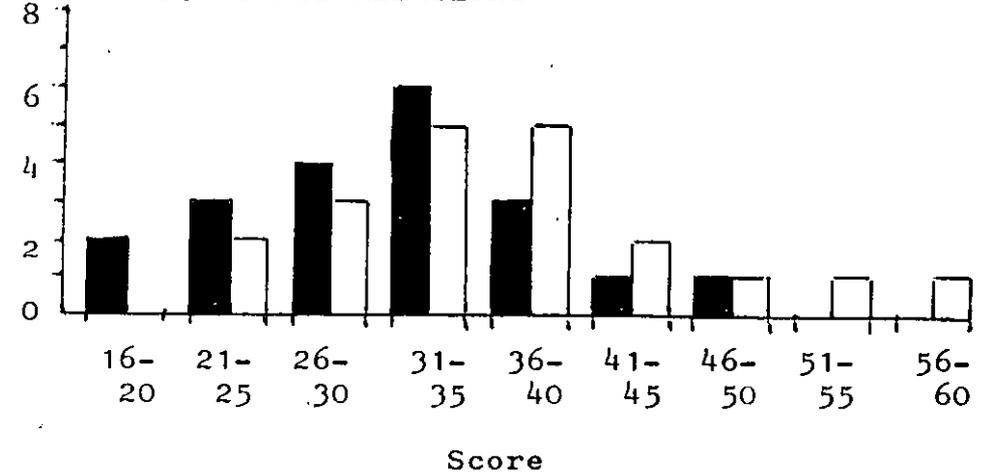
FIGURE 14 : Mean Values for males and females in 18-years age group on Bennett DAT (from Bennett et al., 1966).
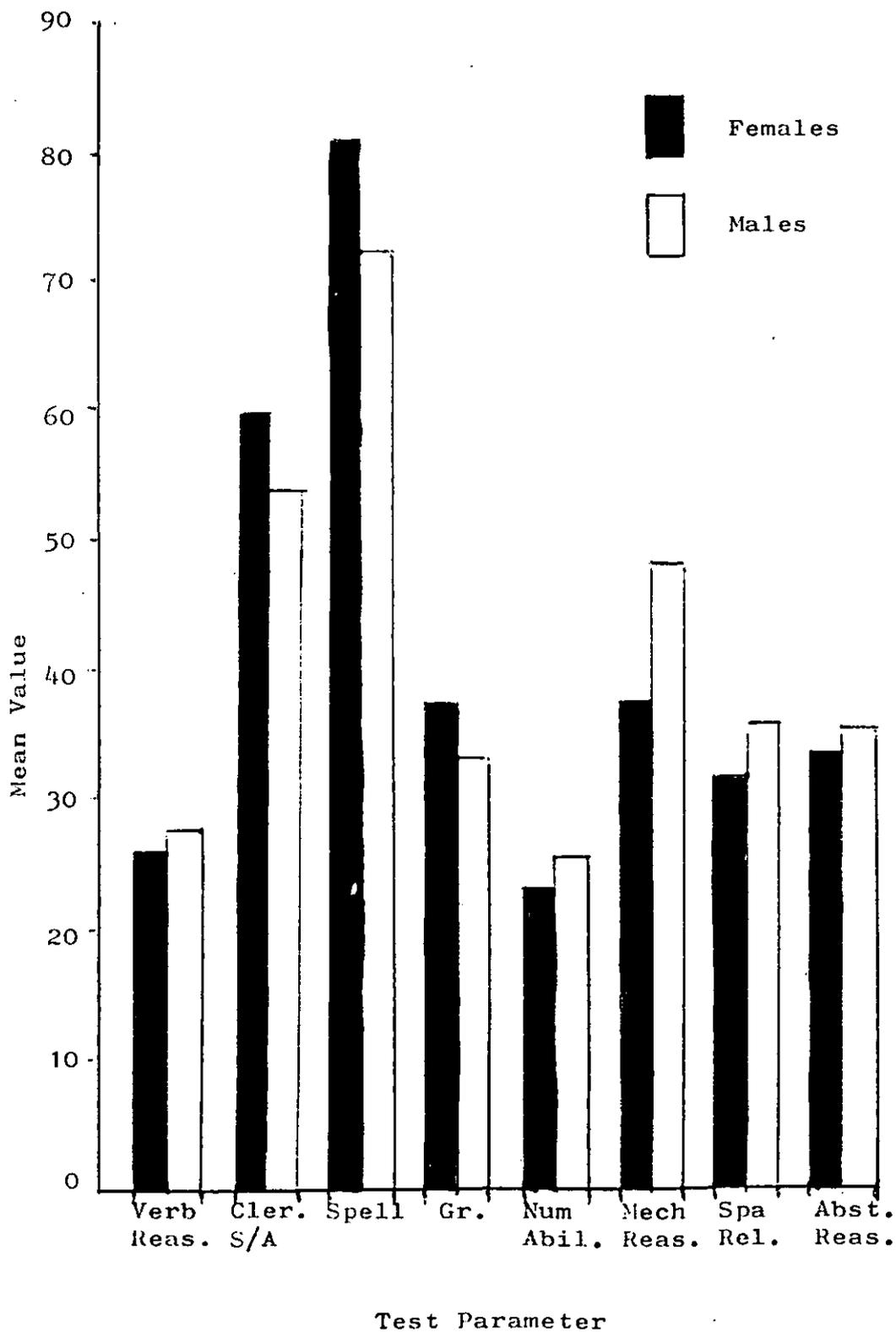
1. VERBAL REASONING & GRAMMAR
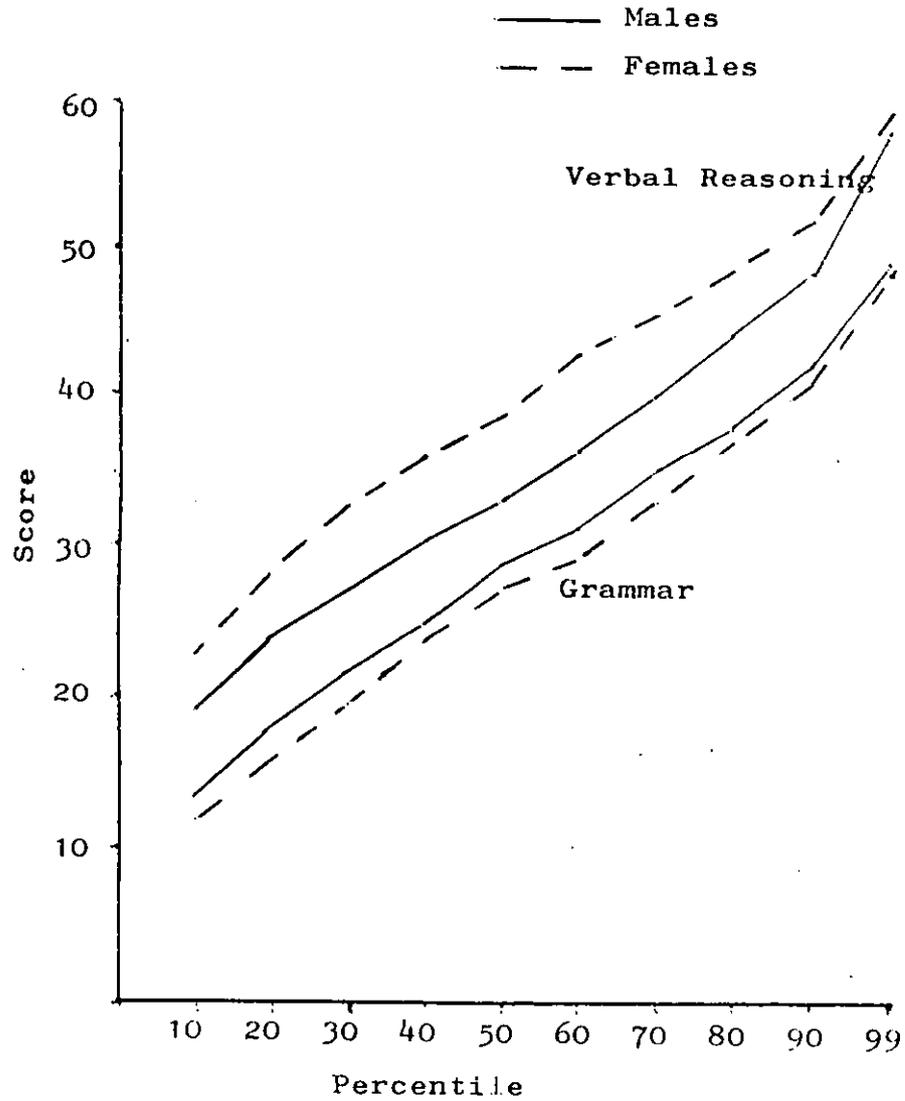
2. CLERICAL SPEED/ACCURACY & SPELLING
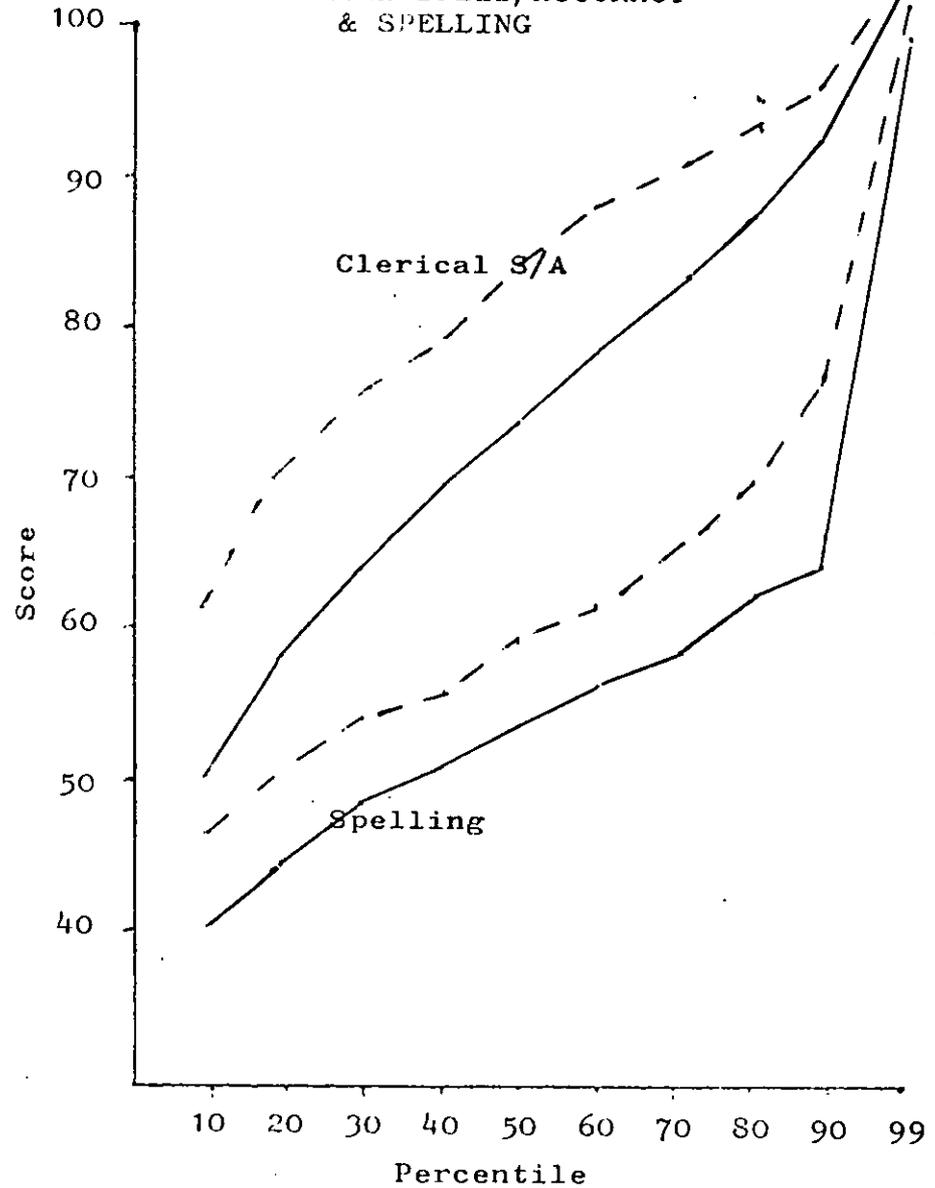
FIGURE 15 : Percentile Norms for males and females in 18-years age group on Bennett DAT (from Bennett et al., 1966). 1. Verbal Abilities

1. NUMERICAL ABILITY & ABSTRACT RESONING

2. MECHANICAL REASONING & SPACE RELATIONSHIPS

Males
Females

Numerical Ability

Abstract Reasoning

Mechanical Reasoning

Space Relationships

Score
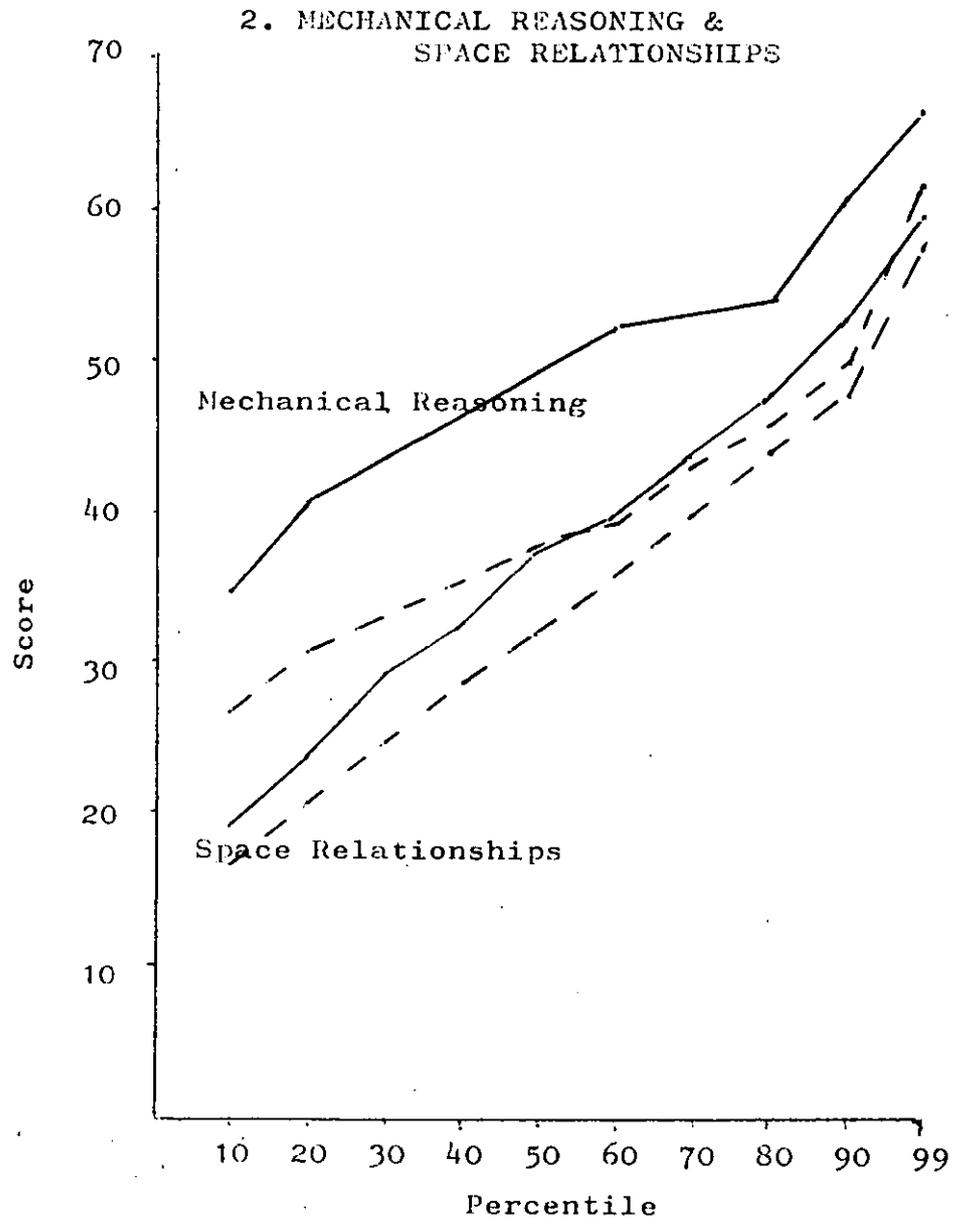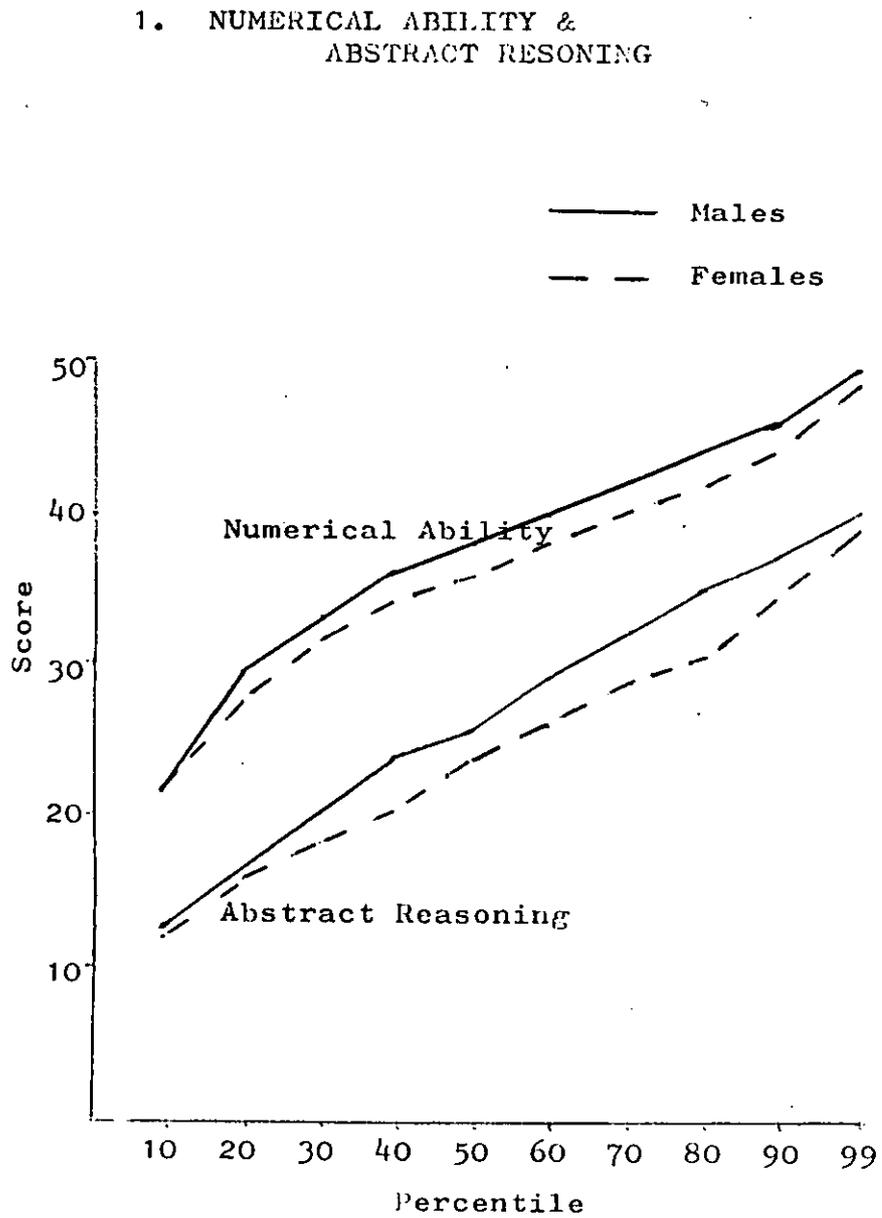
Percentile

FIGURE 16 : Percentile Norms for males and females in 18-years age group on Bennett DAT (from Bennett et al., 1966). 2. Non-verbal Abilities

- 182 -

Thus despite their considerable disadvantage in aspects of language usage, boys are nevertheless able to perform as well as, or better than, girls at tasks employing verbal reasoning. The discrepancies underscore the importance of distinguishing between different types of verbal function since there is no evidence that ability in the executive aspects of language has any bearing on the ability to manipulate verbal concepts. A similar distinction seems to be evident in numerical ability. Tyler (1965) states:

"At the lower age levels, kindergarten and below, where number tests involve simple counting or identification, and on tests for all age levels where only 'mechanical arithmetic' is involved, differences do not appear ....

It is solving problems with numbers that boys manage more successfully than girls."

This has lead Hutt (1972) to maintain that where reasoning or the logical manipulation of concepts of relationships are concerned, males are superior, irrespective of the content of the problem, i.e. numbers, words or patterns. The data presented in Table 45 does show significant differences between the mean scores obtained for males and females in space relationships and mechanical reasoning, in favour of the males. In the other tests of reasoning, however (verbal reasoning, abstract reasoning and numerical ability) although the mean score obtained for males was greater than that obtained for the females, the difference was not statistically significant. Thus the data obtained in this study does not support an over-all superiority for males on tests of reasoning. Furthermore, one might have anticipated from Hutt's suggestion, that there would be a significant, positive relationship between all tests of reasoning (indicative of some 'g' factor operating across these tests). In Table 46 it can be seen that there is a significant positive relationship between abstract reasoning and all the other reasoning tests, but verbal reasoning was significantly related only to abstract reasoning and not to the other tests of reasoning. This suggests that the content of the problem is important in determining the individual's ability to reason.

It should also be noted from Table 46 that there is a high and significant inter-relationship between all tests involving verbal usage (reasoning and manipulation) with correlation coefficients greater than 0.8 being obtained. This would appear to be in conflict with the earlier

comments concerning sex differences in verbal abilities.   Clearly the
verbal factor in such tests is sufficiently strong for performance on each
of them to be closely related.   The existence of significant and strong
relationships between space relations, mechanical reasoning and numerical
ability would have been expected in view of the literature on sex differences
in performance in these abilities.

CORRELATIONAL ANALYSIS: SENSORY PARAMETERS vs. COGNITIVE ABILITIES.

1.   Auditory parameters: In determining which sensory parameters
may be influential in the differential development of cognitive abilities
in the two sexes, it is necessary to determine first those parameters in   •
which significant differences exist between males and females, and second
whether any significant and consistent relationship exists between those
parameters and performance in tests of cognitive abilities.   In Chapter 4,
results were presented which showed that in the auditory modality, significant
differences existed in two parameters - sensitivity at threshold at some
frequencies and tolerance of intensity across the frequency range.

Earlier in this section mention was made of a proposal by McGuinness
(1975) that females attend more readily to sounds - specifically those that
vary in intensity, such as speech and music, and this gives rise to the
reported female superiority in some verbal abilities (see also Chapter 2).
The data presented in Tables 47, 48 and 49 are consistent with this proposal.
Significant relationships are not established between sensitivity at threshold
or discrimination of pitch and verbal abilities, but in Table 48 very high,
significant, negative correlations (p > 0.01) are presented for both sexes
between the setting of just uncomfortable levels of auditory intensity and
the verbal usage tests of spelling and grammar, and also the other verbal
tests.   Thus individuals who are sensitive to high sound levels score more   ·
highly on verbal ability tests.   This is in accord with McGuinness'
proposal (1975) and indicates that tolerance of sound intensity could well
be the significant auditory parameter in influencing the development of
verbal abilities in individuals.   We shall be returning to this discussion
in the next chapter.

2.   Visual parameters: In the visual modality, the results are less
clear and conclusive than for the auditory mode.   There are no consistent
significant relationships established between visual parameters and those
cognitive abilities with which they might have been expected to associate.

The results for sensitivity at threshold (Tables 50, 51), show no relation-
ships with performance on the space relations, mechanical reasoning or
numerical ability tests.   In Table 52 results for the subjective response
to glare intensity show no relationships with cognitive parameters for the
total sample.   Only two significant relationships are established in
Table 52, a negative relationship ($p > 0.05$) for the males between numerical
ability and glare, and a positive relationship ($p > 0.05$) for the females
only between mechanical reasoning and glare.   Had the first relationship
held for both groups and the total sample, it would have been in accord with
McGuinness' proposal (1975) that response to intensity in the visual
modality determined cognitive development in visual spatial abilities.
However, no such consistent relationship was established, and the second
finding is also inconsistent with McGuinness' proposal.   Since, moreover,
no significant difference between the sexes in their response to intensity
in the visual modality was established for this study, the findings do not
support McGuinness' hypothesis.

In view of the findings reported earlier (Chapter 5) that a significant
difference existed between the males and females in visual acuity in this
study, a more interesting relationship for this thesis is that shown in
Table 53 between visual acuity and space relations for the total sample.
This will be discussed further in the next shapter.

CHAPTER 7

CONCLUSIONS

INTRODUCTION

In Chapter 1 reference was made to a comprehensive review of sex differences undertaken by Garai and Scheinfeld in 1968. In this review the authors cite evidence which indicates that from an early age males and females differ in their responsivity and sensivity to visual and auditory stimuli. Thus they suggest that one might postulate a 'visual stimulus hunger' for boys and an 'auditory stimulus hunger' for girls. They further imply if such a difference in sense modality preference were established, this would give rise to different perceptual biases which would provide an explanation for the reported superior performance of females in verbal tasks, and of males in visuo-spatial tasks. Such an explanation would, of necessity, infer that differences in performance on these cognitive tasks would be primarily biological in origin.

This suggestion, supported by an accumulation of evidence which has been quoted in Chapters 1 and 2, has given rise to a number of hypotheses. This thesis has attempted to investigate these hypotheses, using a group of young adult subjects. Sex differences in visual and auditory parameters were investigated using psychophysical methods of investigation, and performance in cognitive abilities was investigated through the use of a differential aptitude test.

In determining the relative contributions of cultural and biological factors to human behaviour, researchers are faced by considerable methodological problems, and are essentially limited to two approaches. In some studies a deductive approach is adopted. These present evidence obtained from lower species by intervention in the normal biological functioning of the animal, or alternatively from case histories where a biogenetic imbalance has occurred in lower-order mammals or in humans. Such evidence is then used as a basis for arguments concerning differences found between human groups. In other studies an inductive approach is utilised. In these, an attempt is made to uncover differences between the sexes for which no cultural antecedents can be found, both from a search of investigations into the behaviours of very young infants and from an assessment of performance in those parameters which are least

likely to be affected by learning.   Consideration is then given to
the relative plausibility of both biological and cultural arguments.
This thesis has adopted the latter approach.

In both approaches problems arise in the interpretation and
discussion of results, and caution is necessary in making assessments
from such studies.   In the deductive type of study, one cannot always
infer that the way in which a lower-order mammal reacts to a situation
will parallel the reactions of the human.   Even in studies where human
subjects have been used, anomalies arise following either abnormal
intervention with biological functioning, or an assessment of individuals
with abnormal chromosomal development.   For example, Money, Hampson
and Hampson (1955a; 1955b), having investigated cases of abnormal sexual
development and hermaphroditism, found that many of these sexually
abnormal individuals adjusted adequately to their sex of assignment
irrespective of their genetic or hormonal sex.   They concluded that
sexuality is undifferentiated at birth and becomes differentiated as
masculine or feminine in the course of the various experiences of
growing up, thus lending support to a cultural determination of behaviour.
In attempting to refute this argument, Diamond (1965) amassed an impressive
body of evidence to support his theory of psychosexual differentiation
at birth.   In a later study Money had given ground sufficiently to
state that the data obtained suggested that there could be a fatal
hormonal effect on subsequent psychosexual differentiation, albeit a
limited one (Money and Erhardt, 1968).   Hormone studies, too, can have
paradoxical results, and mention has already been of such studies as those
of Klaiber et al. (1971), Peretti (1969) and Harris (1970), which
present evidence of such results.

In the inductive study, the main problem revolves around the
objectivity of the researcher.   The arguments stemming from an
investigation will depend largely upon the viewpoint of those undertaking
the research, and they in turn will be influenced to a greater or lesser
extent by the cultural ethos in which the study is undertaken.   It is,
therefore, with some trepidation that the results of this study are
discussed in relation to the hypotheses outlined in Chapter 1.

HYPOTHESIS 1:   Females have a greater sensitivity to auditory stimuli
than males.

As stated here, the hypothesis implies that females have a greater
auditory sensitivity than males, irrespective of frequency, task or type

of input.   This suggests that hearing is a unitary phenomenon.   In this investigation, three auditory parameters have been employed - absolute threshold, subjective reaction to intensity and discrimination of pitch.   If this hypothesis is acceptable, all the parameters tested should show a superiority in favour of the females, and one would anticipate the existence of significant relationships between performance in each of the three paramters.

As stated in Chapter 4, few studies on the auditory modality appear to have investigated more than one task, although evidence exists relating absolute threshold for intensity to the slope of loudness function (Hood, 1968; Stephens, 1971; Schneider et al. 1972).   Even where such evidence exists, however, the studies do not provide information across a wide range of frequencies.   Consequently, the data collected and presented in Chapter 4 is of interest.   The results show that in 6 of the 8 frequencies tested, significant relationships were established for the total sample of men and women between absolute threshold and the subjective reaction to intensity (280 Hz, 500 Hz, 3,000 Hz, 4,000 Hz, 6,000 Hz, $p > 0.01$; 8,000 Hz $p > 0.05$).   No significant relationships were established for 1,000 Hz or 2,000 Hz, and when the two sexes were separated, the results were remarkably inconsistent with relationships being established for males only in some frequencies and females only in other frequencies.   Correlations are in all instances low, and this, together with the lack of consistency seen in the results for single sex groups, detracts from the certainty with which one would propose a relationship between the two parameters.

Similarly no consistent relationship could be demonstrated for either sex between pitch discrimination and absolute threshold at 500 Hz and 1,000 Hz (the two reference tones used).   Again, however, there was a significant relationship ($p > 0.05$) for the total sample, but the lack of consistency in the results once more limits the conviction with which one might argue for a relationship between performance in the two parameters.

In addition to these findings, correlations between performance at threshold, for different frequencies were surprisingly inconsistent for both sexes across the whole range of frequencies tested.   Furthermore, individual subjects varied quite distinctly in their response at different frequencies.   Only in their subjective reaction to 'uncomfortable loudness' did individuals show consistent levels of performance across the frequency range, and higher significant correlations were obtained.

In view of these results, it is difficult to argue with any
conviction that hearing is a unitary phenomenon, and the concept of an
'auditory stimulus hunger' for females as proposed by Garai and
Scheinfeld (1968) would appear to be somewhat naive.   Furthermore,
females are not, according to the results presented in Chapter 4,
superior in all auditory tasks, and there is a need therefore to
ascertain in which tasks females are consistently superior to males.

Of the three auditory parameters investigated in this study,
significant differences between the sexes are apparent in only two -
absolute threshold and the subjective reaction to intensity.   No sex
differences were discernible in performance on the pitch discrimination
test.

The greater sensitivity of females in response at threshold for
some frequencies found in this study has been demonstrated in a number
of earlier studies (Corso, 1959, 1963; Eagles et al. 1963; Hull et al.
1971; McGuinness, 1975).   All demonstrate a superior sensitivity in
the higher frequencies,.   Significant differences at low frequencies
(below 500 Hz) are not reported elsewhere, but Corso does report superior
mean performance by females at all frequencies (Corso 1963).   It does
seem, however, that frequency is important in amplitude detection, since
no sex differences are reported at certain frequencies.   Thus, even for
threshold, where considerable evidence exists, one can not argue for a
greater female sensitivity as such - it depends on the frequency at
which the stimulus is presented.

Only in their subjective reaction to intensity are females
consistently more sensitive to auditory stimuli than males across all
frequencies, both in this and in earlier studies (Zaner et al, 1968;
Elliott, 1971; McGuinness, 1975).   This is apparently true not only
for the young adult group, but also for younger subjects (Elliott, 1971)
and also holds good for variations in methodology (McGuinness, 1971)
and types of input (Pishkin and Blanchard, 1964; Zaner et al, 1968).

Thus the findings of this study clearly demonstrate, in common with
earlier studies, that females have a greater sensitivity to some auditory
stimuli than males.   However, the hypothesis as stated is too naive
and can not be accepted in its entirety.   There are auditory tasks in
which the sexes do not differ, and moreover in parameters where sex

differences are discernible, they may not exist across the whole range
of frequencies.

HYPOTHESIS 2: Males have a greater sensitivity to visual stimuli
than females.

As with the auditory modality, three visual parameters were explored
in this study - threshold (as measured by a standardised adaptometry test),
subjective reaction to intensity (glare) and discrimination (as measured
by a standardised visual acuity test). Again, the hypothesis implies
that males are superior in all visual tasks and that significant
relationships exist between performance in all the parameters tested.

In fact, however, the correlational data presented in Chapter 5
provide little in the way of stable correlations between tests in the
visual modality. Similar findings have been reported in earlier studies
(Ippolitov, 1972; Nebylitsyn and Gray, 1972; Strelau, 1972; McGuinness,
1975). Relationships were established, however, between visual acuity
and threshold, and between the rate of dark adaptation and sensitivity
to glare intensity for both sexes.

It was not expected that relationships would be established between
visual acuity and any other parameter, Rubin and Walls (1969) in their
extensive research on visual acuity report that laboratory investigations
have never yielded such a relationship. Nevertheless, the relationship
between visual acuity and absolute dark adaptation threshold has been
established and it is argued elsewhere in this study that the unaided
myopic individual does have poorer dark adaptation than someone with
normal vision, and that the relationship does not disappear when myopic
subjects have corrected to normal vision by the use of an artificial lens.

The relationship between the initial rate of dark adaptation and the
reaction to glare intensity also suggests a link between a photopic and
a scotopic process. As has been stated in Chapter 5, the relationship
would appear to be between the rate of dark adaptation and the rate of
light adaptation. This may be due to local retinal changes but could also
suggest the involvement of central control mechanisms.

The establishment of a relationship for the total group, and for
females between the level of dark adaptation and the subjective reaction
to intensity, leads one to suppose that vision is a more unitary modality
than hearing. However, when correlational analysis is applied to the

data on these tests and performance on other visual tests not included in this study, such as peripheral vision and colour discrimination, significant relationships are not established (Rowe 1978). It is difficult therefore to argue with any conviction that vision is a unitary modality.

So far as males having a greater sensitivity in visual tests is concerned, the findings for the visual modality in fact give rise to fewer significant differences between the sexes than were evident in the auditory modality. If one ignores the findings associated with the menstrual cycle (which will be considered later), only the data obtained for visual acuity (discrimination) shows a significant difference in favour of the males (p > 0.01). This result parallels the findings of other studies (Roberts, 1964; Burg and Hulbert, 1961; McGuinness, 1975) and is due primarily to females being better represented than males at the high end of the visual acuity scale, and males at the lower end (6/5). The mean performance for males in the reaction to glare test was very much lower than that of females, but no statistical significance could be attached to this result, and individual differences between subjects of both sexes were considerable.

As with the hypothesis for the auditory modality, the findings of this study indicate that this hypothesis is too naive and can not be accepted. There are visual tests in which no significant differences are discernible between the sexes, but in visual acuity males are shown to be superior.

HYPOTHESIS 3: Superior sensitivity to auditory stimuli is related to the superior development of verbal skills.

Since it has already been demonstrated that the auditory modality is not a unified entity, and superior performance in one auditory parameter does not necessarily mean superior performance in other auditory parameters, this hypothesis, like hypothesis 1 must be rejected, in the form stated.

Moreover, just as one sex was not shown to be superior in all auditory tests, so research evidence indicates that one sex is not superior in all verbal tests. Garai and Scheinfeld (1968) list a number of studies investigating differences in performance between the sexes in verbal ability and conclude that in only very few of the verbal sub-tests are females unambiguously superior. Females do not, overall, obtain higher verbal IQ's, and the evidence suggests that it is in verbal fluency that females

excel, rather than in the grasp of verbal meanings or the possession
of larger vocabularies than men.   In Table 54 it can be seen that on
the Bennet D.A.T. the mean for males is slightly higher than for females,
whereas on the language usage tests, females have the higher mean score
(these findings also hold good for the sample investigated in this study).
It is important, therefore, to distinguish between the different types
of verbal function, since there is no evidence that ability in the
executive aspects of language has any bearing on the ability to
manipulate verbal concepts.

In terms of this hypothesis, however, what is interesting is
whether any significant relationship can be established between any
of the auditory parameters (particularly those in which there is
indication of a sex difference) and performance in the verbal sub-tests
of the Bennett DAT.   In Chapter 6 (Tables 47, 48 and 49) correlation
coefficients are presented for the total sample, males and females
between each of the parameters tested by the DAT and the three auditory
parameters.   Whilst no consistent significant relationships were
established between either pitch or auditory threshold and any of the
differential aptitudes parameters, very high, significant negative
correlations $(p > 0.01)$ were obtained between the subjective reaction to
auditory intensity and all the language/ language usage parameters.
It would appear that the less tolerance an individual has of high
noise levels, the higher he or she scores on the DAT in verbal
reasoning, clerical speed and accuracy, spelling and grammar.

This is particularly interesting since reaction to auditory
intensity is the one auditory parameter in which a significant
difference exists between the sexes across all modalities, and we shall
return to this discussion under Hypothesis 5b.

HYPOTHESIS 4:   Superior sensitivity to visual stimuli is related
to the superior development of spatial-mechanical skills.

Like the auditory modality, vision is not a unitary modality,
and an individual may display superior performance in one visual parameter
and not others.   For this reason this hypothesis, like those already
discussed, is untenable in the form stated.   It may therefore be more
productive to examine whether or not significant relationships exist
between any of the visual parameters tested and the spatial-mechanical
sub-tests of the Bennett DAT.

Perusal of Table 45 shows that Space Relationships and Mechanical Reasoning were the only two sub-tests in which statistically significant differences between the sexes (in favour of the males) were observed for this sample (p> 0.05 and 0.02 respectively). The establishment, therefore, of a significant relationship between these two parameters and a visual parameter showing a similar sex difference in performance would be most interesting for this study.

As has already been stated in the previous chapter, however, the correlations between the visual parameters and these aptitudes provide few consistent significant relationships. A positive relationship between sensitivity to glare and mechanical reasoning was established for females (p> 0.05) but not for males or the total sample. Similarly a negative relationship (p> 0.05) was established for males between sensitivity to glare and numerical ability (another parameter in which males are separately superior), but the relationship does not hold for females or the total sample. In fact the only relationship established for the total sample was between visual acuity and space relations (p> 0.05), but this does not hold for the two single sex groups (partly due, perhaps, to the large number of ties in each group). The relationships between visual acuity and either mechanical reasoning or numerical ability do not reach statistical significance, however, although it is true that they are higher than for other parameters. This will be referred to again under hypothesis 5b, since visual acuity was the one visual parameter in which a sex difference was established.

HYPOTHESIS 5a: There is a difference in auditory and visual sensory sensitivity between the sexes which is biological in origin.

We have already established that neither sex displays an overall superiority of performance in either modality. Nevertheless some of the data have revealed significant sex effects, and even those findings where no sex differences have emerged may be equally valid in providing clues about the nature and development of sex differences, particularly when seen in conjunction with the evidence provided from earlier studies.

While the experiments reported in chapters 4 and 5, in conjunction with the research reviewed in chapter 2, provide vital information on these issues, experimental evidence from the studies presented here are not always easy to interpret. In chapters 4 and 5 an attempt was made to discuss the origins of the sex differences observed in terms of physiological systems, and when relevant, in terms of genetic and/or

cultural effects. However, it must be emphasised that the attempt is speculative. In assessing data in terms of physiological systems, one attempts the rather dubious task of separating peripheral and central effects. That this attempt may be grossly inaccurate at the present stage of our knowledge does not militate against the merit of trying to pinpoint certain structures in which sex biases are more likely to occur. In attempting to specify mechanisms, it can be seen that certain of the data are more amenable to such speculation than others.

In Chapter 1 some of the current theories proposed as explanations for the existence of sex differences in a number of behavioural characteristics were discussed. To reiterate briefly, psychologists have traditionally explained these findings in terms of differential learning, and focus on society as the prime determinent of masculinity and feminity. Once the child has been reinforced for sex-appropriate behaviour, it becomes increasingly difficult for him or her to change to the other one without considerable conflict and tension. All the details of the general sex differences in behaviour are thought to arise from these culturally imposed restraints. It is difficult, however, to assign the differences in performance between the sexes found in this study to any acculturation hypothesis. For example, in the auditory modality, females were found to be more sensitive than males both in threshold detection of high (and very low) frequency tones, and in their subjective reaction to intensity. Cultural explanations would presumably suggest that males were subjected to noise more than females and were thus more used to it or had in fact suffered slight damage to the ear as a result. However, the young people used as subjects were from similar backgrounds and had been subjected to little or no work experience which might damage the ear - and both sexes attended noisy discos. Furthermore, so far as threshold is concerned, in an earlier study Corso (1959) controlled for a number of environmental effects, but still found significant differences in favour of females at many frequencies.

For auditory intensity one might suggest that the sexes have different semantic biases as a result of acculturation, and that these biases might affect their interpretation of 'just uncomfortable loudness'. To justify this, however, an argument would have to be proposed in which cultural factors influence the way the sexes are taught to label their reactions to sound but not to light (see Chapter 5). Two other findings militate against an explanation in terms of linguistic effects. Elliott (1971) produced results in children where mean dB levels in 'just

uncomfortable loudness' between the sexes were virtually identical to those found in this study.   Although this is not by itself . a strong argument, since linguistic biases could be established very early, nonetheless one might expect either an increase in such a bias to occur developmentally or regression away from the bias with subsequent experience. Further, studies by Pishkin and Blanchard (1961) and Zaner et al. (1969) have demonstrated, using children and adults, that females are more sensitive to intensity than males in auditory concept tasks.   Since these tests require an objective response, either recognition or reproduction, effects due to linguistic biases are eliminated.

In the visual modality the male superiority in visual acuity also poses problems for acculturation hypotheses in terms of what initiated the environmental effect, and what form does it take.   Emphasis on the visual systems might be expected to cause deterioration rather than improvement. One might suggest that females may become more myopic because they spend more time reading and doing close work, while male acuity may become more efficient because of their greater interest in physical activity and sport. However since all the subjects used in this study were specialist physical education students with similar interests and educational attainment, such an argument lacks plausibility.

One must therefore consider the implication of biological factors in explaining sex differences in these sensory parameters, although it must be pointed out that certain of these sensory processes may be more plastic than others - the finding that performance on the pitch discrimination test correlated with the degree of musical training which the individual had, suggests an important environmental effect on this type of ability. Pottós (1974) has shown that training in certain types of games has considerable effect on peripheral vision, suggesting that this too may be one of the more plastic sensory processes.   Even here, however, innate sensitivity may not be entirely disregarded.   Bentley (1966) certainly favours a genetic determination of musical ability, and it is not easy to determine whether musical people undergo musical training because they have a discriminating ear, or whether the training increases their ability to discriminate.   Similarly games players may be attracted to certain games because they have the attributes required for those games (including peripheral vision), as well as the games training developing the appropriate attributes.

Acceptance of biological involvement in explaining the sex differences shown in Chapters 4 and 5, however, is not without its problems, since biological explanations may take a number of forms, and one must try to evaluate these as explanations of the data obtained.

Developmental lag theories (see Garai and Scheinfeld, 1968) argue that while both sexes go through virtually identical developmental stages, the female's more advanced physical maturity leads to her always arriving at a developmental stage earlier than the male. The findings for visual acuity in this and other studies of adults (Roberts, 1964; Burg, 1966) when related to infant and child studies, where no differences in performance between the sexes are found (Fagan, 1972; Skoff and Pollack, 1969) are consistent with this theory. It can not, however, explain the findings for auditory threshold and intensity. Females retain their superiority at threshold throughout life (Corso, 1959) and remain more sensitive to loudness (Elliott, 1971; McGuinness, 1975), where one would expect, if the theory were correct, that the differences would disappear in adulthood.

Cerebral dominance theories, as has already been discussed, relate predominantly to the differences observed between the sexes in verbal and visual-spatial abilities. It has been suggested, however, that such theories also contribute to a more general treatment of sex differences in the emotional and cognitive behaviour of mammals (Buffery and Gray, 1972).

Whilst no mention was made by Buffery and Gray of the sensory modalities which might serve the development of linguistic and visual-spatial skills, it would seem feasible that differences between the sexes in the auditory and visual modalities might relate to those differences outlined in relation to the two cognitive abilities. In consequence, cerebral dominance hypotheses might be expected to provide reasonable explanations for the sex differences in the two modalities outlined in Chapters 4 and 5. The finding that females have superior sensitivity in auditory intensity threshold and intensity tolerance, while males have superior visual acuity and peripheral vision, would certainly appear consistent with cerebral dominance theories, but they would also seem to predict differences in pitch discrimination and in visual threshold and intensity, where none were found. The findings for laterality are similarly anomalous. Buffery and Gray report findings by Kimura (1964), Chaney and Webster (1965) and Curry (1967) indicating that for the type of input employed

in this study (designated 'difficult to verbalise') most subjects
display a left-ear advantage at threshold.   Over-all this was also
found in the present investigation, but some subjects had superior
performance with one ear at some frequencies and with the opposite
ear at other frequencies.   In the visual modality, too, Buffery and
Gray report findings by other researchers indicating a best eye
performance for the right visual field for 'easy to verbalise' stimuli
(Mishkin and Forgays, 1952; Heron, 1957; Bryden and Rainey, 1963)
and for the left visual field for 'difficult to verbalise' stimuli (Kimura,
1966), whereas in the present investigation it was common to find no
difference in performance between the eyes on the test of visual
acuity.   Furthermore, since in visual acuity no difference is found
between the sexes until the mid-teens, one can not rule out the
argument that hormonal influences might be implicated.   Thus the
findings of this and other studies do provide some difficulties for
the acceptance of cerebral dominance explanations as the only determinants
of differences between the sexes.

Some discussion has been given to hormonal theories throughout
this thesis, and evidence has been presented in earlier chapters
supporting the suggestion that both male and female hormone levels are
implicated in differential performance by the sexes in a number of
parameters.   Hormonal explanations may take the form of developmental
structural differences between males and females, or may centre around
the importance of adult levels of the sex hormones.

In Chapter 1 reference was made to a review by Hutt (1972), in
which she concludes that from the very early weeks of uterine life,
males and females develop in characteristically different ways, under
the influence of the respective genetic complements, which confer special
properties on the course of development, and the gonadal hormones,
particularly testosterone, which have important formative and organisational
functions.   Differences in structure, metabolism, physiological and
psychological functions then characterise the development of the two
sexes from the moment of birth onwards.

The possibility that sex differences in performance in the auditory
modality may be accounted for in terms of structure or physiological
differences has been discussed in Chapter 4.   Three possible explanations

were proposed. Ward (1966) suggests that women have more delicate
middle ear muscles, a view that accords well with other findings on
sex differences in small muscle and gross muscle systems (see Chapter
2). Christman (1971), on the other hand, suggests that the density
of those hair cells which respond to high frequency tones is greater
in females at the stapes end of the basilar membrane, where high
frequency sensitivity is maximal. Either of these proposals may be
applied to the findings for absolute auditory threshold, but they lack
plausibility as explanations for the findings for 'uncomfortable loudness'
since they would imply that females would be significantly more sensitive
at some frequencies only, whereas the sex difference is remarkably
consistent across the whole frequency range tested. Both proposals
could be verified by anatomical and histological techniques, but it appears
that neither hypothesis has been pursued, and it may be that the greater
sensitivity of females may not be due to mechanical structure, but is
located in such higher centres as the inferior colliculi and the superior
gyrus of the temporal lobe. It is known that damage to these centres
severely affects the detection of fine differences between frequencies
and between intensities (Evans, 1974; Milner and Teuber, 1968), but
there appears to be no evidence showing whether lesions to these structures
affect threshold for specific frequencies.

To determine where the effect of sex differences is maximal, it
would be possible to carry out the anatomical studies referred to above,
and to study the effect on hearing thresholds in patients with lesions
in the higher auditory systems. However, it would probably never be
possible to determine the solution to this issue on an either/or basis.
Differences in transduction by peripheral systems would serve to produce
selective differences in higher order neurones, as has been repeatedly
demonstrated (Pribram, 1971).

For the visual modality the superiority of males in visual acuity
may also be explained in similar fashion. In subjects with gross acuity
deficiencies, abnormalities of the lens or lens muscle may be implicated
(see Chapter 5). However, that the lens is unlikely to be the only
factor involved is suggested by the numerical domination of the males
in the superior to normal range. Lesions of the occipital centre,
particularly the foveal strata region, are known to impair visual acuity,
and higher centre involvement cannot be discarded. Moreover, the late
appearance of sex differences in this parameter (Fagan, 1972; Skoff and

Pollack, 1969) suggest either that learning or maturation may be involved, and it may be that a different type of hormonal explanation involving adult levels of sex hormones may prove more productive.

This type of explanation has been proposed by both Broverman et al. (1968) and Andrew (1972). In essence the proposal is that androgens affect central neural mechanisms in one way, whilst female hormones (particularly oestrogens) have a different effect. To some extent, therefore, suggestions of higher centre involvement in some of the previous explanations of sex differences may relate to this type of proposal. Andrew (1972) derived his hypothesis from work on food-searching strategies in young male chicks injected with testosterone, in which he found that testosterone leads to increased 'persistence'. He then suggested that testosterone operates in vision by stimulating foveal mechanisms and suppressing peripheral vision. This could explain the late appearance of the superior ability in males, but as yet Andrew's suggestion appears to be demonstrable only in chickens. Its validity in humans could perhaps be tested by assaying the levels of circulating testosterone in males at the extreme ends of the visual acuity scale.

Support for this type of explanation is also provided by the findings in this and earlier studies concerning the effects of the menstrual cycle on performance in females. In the auditory modality significant differences at threshold between the males and the pre-ovulatory group are present at more frequencies than between males and the other two sub-groups, suggesting greater responsivity to auditory signals during the pre-ovulating phase as a result of chemical changes in the receptor mechanisms brought about by cyclical hormonal changes. Support for these findings are presented by Baker and Weiler (1971) who monitored their females throughout their menstrual cycle. Similar results were obtained for auditory intensity whilst in the visual modality the findings support those of Diamond et al (1972). Using the same sub-groups as this study and that of Baker and Weiler (1977), they found that sensitivity to low levels of light was greatest at mid-cycle in normally menstruating females and remained high until it declined abruptly at the onset of menstruation. Two explanations for this might be proposed. The first relates to the auditory findings, suggesting that cyclical hormonal fluctuations in females affect the higher centres, making them less sensitive to visual stimuli in the pre-ovulatory phase. Alternatively the changes might affect rod sensitivity, which is itself

a chemical process. However, hormonal influences in adulthood can
not be the sole explanation of differential performance between the
sexes, since Corso (1959) and Elliott (1971) have shown that in the
auditory modality these differences exist even before puberty.

Thus, on the findings of this study, particularly when related
to other findings, the acceptance of a purely environmental explanation
of sex differences in the parameters discussed becomes untenable.
On the other hand, no single biological explanation of sex differences
so far proposed can adequately cater for all the evidence. Nevertheless,
biological factors have been implicated as determinants of differences
between the sexes in performance on some auditory and visual tasks.
It seems likely that some or all of the following - hormonal levels,
differences in the central nervous system at cortical and sub-cortical
levels, and differences in the anatomical structure of peripheral
mechanisms - may be involved in determining the differential performance
of males and females in these tasks.

Before leaving this section, one further point should be made.
Cultural and environmental factors are clearly implicated in at least
some of the findings of this study. One of the major weaknesses of
biological determinist arguments has been in the adoption of an
extreme position. Studies of individual differences consistently
show that development involves an interaction of both genetic and
environmental factors. Dividing an individual's behaviour into so-called
innate and learned components, and then emphasising one to the
exclusion of the other is likely to prove an unproductive exercise.

HYPOTHESIS 5b: This difference leads to a sense modality preference
and is related to differences in the development of certain cognitive
abilities.

In Chapter 1 two statements by Garai and Scheinfeld (1968) from
their comprehensive review of sex differences were quoted. The first
suggested that males and females were different in their attraction to
auditory and visual stimuli, with males being more attracted to visual
stimuli and females to auditory stimuli. The second indicated that
if this difference in sense modality preference between the sexes could
be corroborated it would provide an explanation for the apparent tendency
of females to develop superior verbal skills, whilst males excel in tasks
involving spatial perception. In the light of the results of this

study and earlier studies, both statements would appear to be too naive. The within-mode correlations presented in Chapters 4 and 5, and the findings that in many visual and auditory tasks males and females do not differ, indicate that it is impossible to talk of an overall superiority in sensory sensitivity in either modality for either sex. Moreover, as has been pointed out earlier, females.are not superior in all verbal skills.

Nevertheless males and females certainly do differ in their performance in some auditory and visual parameters, and in their performance in tests of some cognitive abilities. Furthermore, the correlational data presented in Chapter 6 between performance in the sensory modality tasks and the cognitive ability tests suggest close links between performance in some sensory tasks and some cognitive abilities. There may thus still be some substance in the implication contained in Garai and Scheinfeld's statement that the sensitivity of a receptor plays an important part in the perceptual process, and thereby influences cognitive and behavioural development.

Support for the suggestion that sensory mechanisms and perceptual biases effect cognitive functioning comes from the findings of Rosner (1973) that "visual" children (those who were more competent in the use of visual information in visual vs. auditory stimulus patterns) were better at arithmetic, and "auditory" children were better at reading. Certain problems arise, however, particularly in relation to the way in which these sensory mechanisms and perceptual biases influence cognitive abilities, and it would seem important to determine the input or informational variables which initiate a cognitive process.

The way in which sensory capacity might contribute to the development of cognitive abilities was outlined in Chapter 1. It related to a model of perception as a process in which each observer is seen as an active perceiver engaged in extracting information from his environment. However, because the observer is limited as to the amount of information he can process, from among the deluge of potential stimuli he is forced to perceive or respond to less than the total array. This process is referred to as selective attention (Broadbent, 1958), and a number of researchers (Gibson and Gibson, 1955; Lindsay, 1970; Honig, 1970) have emphasised the importance of sensory channel discriminative efficiency in this process. Honig, in particular,

suggests that ease of discrimination would appear to affect both the amount of information processed and the modality or channel which reviews attention. Attention is likely to be more easily directed to the most efficient channel, and the modality which contains the greater number of signals which are easy to discriminate, will tend to dominate other modalities.

It is helpful here to consider a model of attetnion proposed by Pribram and McGuinness (1975) in which it is suggested that the final stage of an attentional process, which they term 'reasoning', allows voluntary attention to details of the stimulus and can draw upon the metabolic resources available to put forward the required cognitive effort to carry out the task. A voluntary system can be engaged either because the subject is directed to carry out some task by an outside agent, or because he wishes to perform the task for his own interest and satisfaction. Whichever source is acting as operator, the effort expended will be determined by the experience of the individual, and experience can arise from biases on sensory input and response output, interacting with such external factors as culture, learning and type of reinforcement history. This interaction will determine the exciting and meaningful properties of the input, and there is an inter-relationship between these properties and the inherent capacity of the individual to perform operations upon it. Cognitive ability would appear to be dependent upon both these factors working together.

It is suggested that sensory sensitivity in a specific modality may give rise to an attentional preference, which in turn influences the development of a perceptual bias. This perceptual bias then interacts with certain external factors (Culture, learning, differential reinforcement) to give rise to individual differences in cognitive abilities. If this argument is a valid one, then it may be developed to form the basis for an explanation of differences between the sexes: if the sexes do begin life with a different perceptual bias, this might well interact with other factors to give rise to the adult sex differences in cognitive abilities. Gibson and Gibson (1955) have suggested that discriminative ability plays an important part in the development of perception, and that it is those stimuli which are most 'arousing' which attract attention. Related to this view is the suggestion that the efficiency of the sensory channel by which the

stimulus is received will influence the arousing properties of that
stimulus, and will thereby influence perceptual development.   Greater
attention will be produced by a highly discriminable signal on one
channel, by allotting a greater amount of central capacity to that
channel.   This, in turn, may draw more attention to the modality as
a whole.   The question which must then be asked is - what are the
important variables of an input stimulus related to discriminability?
Pribram and McGuinness (1975) outline a number of such variables,
including the meaningfulness of the stimulus, novelty and, of particular
relevance to this study, intensity changes.   The intensity of a
stimulus has been shown to be an important factor in determining whether
it will be registered in the nervous system (Sokolov, 1963; Berlyne,
1970).   In consequence, McGuinness (1975), on the basis of her
findings that the sexes respond differently to intensity levels of
sound and of light, suggests that reflex attention is produced more
frequently in females to sounds - specifically those that vary in
intensity, and in males to visual stimuli - particularly those with
detectable contrasts in brightness.

    It is, of course, arguable that the setting of subjective comfort
levels of intensity in either modality necessarily relates to the
detection of small changes in intensity, as such.   Nevertheless the
proposal is an attractive one, and would, if it could be validated,
provide a useful description of how sensory sensitivity might lead
to the establishment of a sense modality preference.

    In Chapter 2 evidence was presented which suggested that at
all ages females are more responsive than males to auditory input and
input with auditory-visual associations.   At a very early age they
listen and respond meaningfully to a range of auditory inputs from
an infant's cry to adult speech and music.   They show a very specific
response pattern to auditory and visual information that interests
them, smiling and vocalising, while their motor activity and heart-
rate decelerate.   From infancy to adulthood females continue to be
more sensitive to certain types of auditory input, particularly
intensity changes and localisation of sound.   From 4 to 5 months of
age they show a strong preference for faces over objects, and develop
a strong interest in people and social stimuli (undoubtedly reinforced
by cultural influences).

    It has been suggested by McGuinness (1975) that perception by

females of intensity as subjectively louder than by males may imply both that softer auditory stimuli will attract their attention and that differences in intensity will be more noticeable to them. If this is so, it would help to explain certain other findings. Shuter (1968) has demonstrated that females score particularly well on musical tests involving dynamic interpretations, and that the only distinct differences between the sexes is due to a factor of intensity. It is thus possible that a facility in discerning subtle changes in intensity causes the female to respond with feeling to music from a very early age (Kagan and Lewis, 1965). This same factor may be responsible for producing an emotional reaction to intensity differences in speech (inflection). This would provide an explanation for the findings of Simner (1971) that female infants respond differently from males to the sound of another infant's cry - the females could be responding to inflectional shifts. It would also explain why female infants consistently respond to high-inflection speech, whether it has high or low meaning (Kagan and Lewis, 1965). Sensitivity to the emotional overtones in speech might also relate to the findings of Lewis (1972) that female infants respond more to verbal comforting than males. Speech may then develop faster in the female as she seeks to produce verbal response from the mother by directing her babbling specifically to the mother.

The evidence presented in Chapter 2 suggests that from a very early age boys respond more to visual stimuli than females. They are more attracted to such varied stimuli as blinking lights, complex geometric patterns, coloured photographs of objects and three-dimensional objects (Cornell and Strauss, 1973; Kagan and Lewis, 1965; McCall and Kagan, 1970; Myers and Cantor, 1967; Paneratg and Cohen, 1970). When presented with facial configurations as visual stimuli, boys looked at them for longer than girls (Lewis, 1969), but they appear to be equally interested in faces and objects as visual stimuli, with blinking lights attracting the most interest from them (Kagan and Lewis, 1965). They are also more interested in any novel visual stimuli than girls, who respond most when the stimuli presented are likely to smile and vocalise back.

It is reported in Berlyne (1970) that the factors which influence attention for visual input are brightness (light intensity) and contrast. McGuinness (1975), moreover, found that males respond more to levels

of light intensity than females. These findings could suggest that the attraction for males of visual objects may arise from their greater perception of the contrasts between the various planes and surfaces.

Acceptance of this viewpoint would provide an explanation of how differences between the sexes in sensory sensitivity would lead to the establishment of different perceptual biases, and one might then postulate relationships between these perceptual biases and differences between the sexes in the cognitive abilities outlined in Chapter 2, with females excelling in verbal skills and males in spatial/mechanical abilities.

In this study data·has been presented demonstrating differences between young adult males and females in sensory sensitivity in a variety of auditory and visual tasks.   In particular, in the auditory modality the sexes were shown to differ in their response to intensity, with females being more sensitive.   This is consistent with McGuinness's findings and provides some support for this part of her argument, if one accepts that tolerance and discrimination of intensity are related. Similar evidence has been presented in other studies for different age groups (Elliott, 1971).   In the visual modality, however, although comparison of the means obtained for each sex in the present investigation might suggest that males are more sensitive in their subjective reaction to glare intensity, statistical analysis revealed no significant difference between the sexes.   Only when the males were compared with normally menstruating females in the pre-ovulation phase of their cycle was a significant difference obtained, with males showing greater sensitivity.   This might indicate that significant differences are likely to be found only after puberty.   This poses considerable problems for McGuinness's explanation and further studies on the reaction of males and females to visual intensity in other age groups, as well as in young adults, are required before her explanation can be adequately assessed.   Moreover, as has been indicated earlier, the methodology employed by McGuinness was questionable, being open to a number of subjective interpretations.

Nevertheless, the data presented in Chapter 6 does provide some support for the suggestion that in the auditory modality, at least, response to intensity may be influential in determining performance

in verbal abilities. Consistent, significant (p> 0.01) and high
negative correlations were obtained between the subjective response
to auditory intensity and performance in all those tests on the Bennett
D.A.T. requiring verbal abilities (even in verbal reasoning, where the
literature suggests that there are no differences between the sexes).
In this study, however, no significant, consistent relationships were
established between performance on the spatial and mechanical tests
of the Bennett D.A.T. and performance in any of the visual parameters.
Indeed the only significant relationship which is obtained for the whole
sample is between the Space Relations test and visual acuity - not
response to intensity. Since the difference between the sexes in
visual acuity is not found until after puberty (Fagan, 1972; Skoff and
Pollack, 1969), this finding could not explain the greater response
of male infants to visual input. It may be, therefore, that this
phenomenon may simply be a manifestation of the male's lack of
specialisation in response to auditory input, thus conforming to a
proposal put forward by Buffery and Gray (1972) in their cerebral
dominance theory to explain the greater visual-spatial ability of the
male. It is important to remember, too, that caution should be applied
when interpreting correlational data. The existence of a significant
or negative relationship between two factors simply implies that as one
factor varies so will the other in either a positive or negative way.
It does not imply that there is a causal relationship between them.
Sensitivity to auditory intensity, for example, does not necessarily
cause superior verbal skills - the two variables are simply in a
relationship which may be caused by some other factor entirely.

Thus whilst Garai and Scheinfeld's (1968) proposal that the sexes
start life with different perceptual biases, as a result of sensory
modality preferences, which influence the development of different
cognitive abilities is an attractive one, a cautious interpretation
of the results of this study suggests that this is not the only
argument which might be proposed to explain the findings. Differences
between the sexes have been shown for sensory sensitivity tasks in
the auditory and visual modalities, with females demonstrating
superiority in the performance of auditory tests for threshold and
intensity, and males having superior visual acuity. Moreover,
relationships have been established between reaction to intensity and
some verbal abilities, and between visual acuity and a visuo-spatial
test. Since it has been argued that the sensory sensitivity differences

are biologically determined, it seems likely that the sex differences
in cognitive abilities are also, to some extent, biologically
determined.   Currently the most popular biodeterminist theory is
that of cerebral dominance, which proposes that a linguistic device
for speech perception is subserved by an innate, species - specific,
neural mechanism which is lateralised and localised to the dominant
(left) hemisphere for language (Buffery and Gray, 1972).   Female
superiority in linguistic ability is then a direct consequence of
earlier and greater lateralisation of language in the female under
hormonal and chromosomal influence.   Male superiority in visual
spatial abilities than arises as an indirect consequence of the greater
lateralisation of language in the female, and is located more bi-laterally,
giving better three-dimensional representation.   Buffery and Gray
argue that a consequence of the less well lateralised cerebral
representation of linguistic skill in the male brain might be a more
bilateral cerebral representation of spatial skill than can be
achieved in the female brain.   This is on the assumption that whatever
language functions are subserved by areas of a non-dominant hemisphere
leave equivalent areas in the dominant hemisphere free to subserve
non-verbal functions.   In both sexes there will usually be a
predominance of spatial function in one cerebral hemisphere or the other,
but in general the male brain has, because of its less well lateralised
language function a better opportunity to develop a more bilateral and
therefore a more efficient spatial function.   It is also suggested that
superior spatial ability is dependent upon a recessive gene carried on
the X chromosome (Stafford, 1961), and it has been estimated that this
recessive allele is possessed by approximately 50 per cent of the male
population, compared to only approximately 25 per cent of females (Bock,
cited by Garron, 1970).   There would therefore appear to be good
grounds for accepting the influence of biological determinants on
differences between the sexes in the type of cognitive abilities
outlined in this study.   One could then argue that the superior
performance of females in auditory sensitivity is linked in some way
to the neural mechanism which is specialised for the extraction of certain
linguistic features in speech perception.   Similarly, the tendency of
the male brain to develop a more bilateral and therefore more efficient
spatial function (which is also linked to a recessive allele) may be
enhanced after puberty by the male's superior visual acuity.   This
would provide another explanation of the relationship obtained in
this study between sex differences in sensory sensitivity and those in

cognitive abilities.

Before we can determine which argument is likely to prove more
productive, considerable experimental support is necessary in order
that each may be more realistically evaluated. Anatomical studies,
studies of sensory sensitivity over a comprehensive range of age groups,
studies of sex differences in children deprived of sensory input in one
modality, or unable to move, and studies investigating performance on
learning tasks where more than one type of information is coded
simultaneously would all be required. Moreover, procedural variations
would appear to be critical in obtaining behavioural effects, and
considerable standardisation of techniques would be necessary.

CONCLUSION

In this chapter, the hypotheses outlined in Chapter 1 have
been evaluated. They arise from an interesting proposal by Garai and
Scheinfeld (1969) that the sexes begin life with different sensory
biases in the auditory and visual modalities, which influence the
attention paid to auditory and visual stimuli, and give rise to sex
differences in verbal and visuo-spatial cognitive abilities.

In the light of the findings of this study, the proposal, and
many of the hypotheses implied by the proposal, have appeared too
naive. Hypotheses 1 and 2 were rejected in their stated form -
females do not have greater sensitivity in all auditory tasks, neither
do males have greater sensitivity in all visual tasks. In consequence
hypotheses 3 and 4 were not accepted. Nevertheless the sexes do differ
in performance on some auditory and visual tests. Moreover,
relationships were established between performance on one auditory
and one visual sensory test, and verbal sub-tests on the Bennett D.A.T.
and the space relations sub-test respectively.

In discussing hypotheses 5 (a and b) reference had to be made to
earlier studies. Acceptance of a biological determination of the
differences between the sexes in auditory and visual sensory sensitivity
was argued for in the light of all the evidence, and since these
differences were shown to be related to the development of verbal and
visuo-spatial skills, a biological factor is clearly implicated in
these cognitive abilities. In adopting a bio-determinist viewpoint,

however, it is important to acknowledge the interactive nature of social and biological variables. Throughout this study it has been shown that the sex differences found in cognitive and perceptual tests all refer to means and that the range of values overlap greatly, with relatively small mean differences. Despite the initial difficulties experienced by males in reading and writing (Taylor and Ounsted, 1972), and the fact that in special remedial classes for poor readers, boys are considerably over-represented (see Macoby and Jacklin, 1974), they nevertheless do learn to read and write, and to express themselves fluently verbally. Indeed in this study, no significant differences were obtained between the sexes on any of the verbal tests. Thus it would seem that while initial processes may be guided by certain innate differences, there is no reason to assume that these differences must remain. Parents and teachers insist that boys acquire verbal skills, whereas no such insistence induces the female to learn about spatial, mechanical relationships. Schools do not usually offer remedial instruction in such skills. Thus the male overcomes his initial verbal handicap at school, but by the time certain spatial skills are required by the curriculum, the female may have passed the maturation point for acquiring them easily - it is unlikely that these skills can not be acquired by females!

This thesis makes an informative contribution into the nature of sex differences. Evidence has been found of differences between the sexes in some auditory and visual parameters. Moreover, in some instances relationships have been shown between sensory sensitivity in some of these parameters and performance on differential aptitude tests. The direction of this thesis has shown where significant differences between the sexes in auditory and visual sensory sensitivity exist, and where these are meaningful in the development of important life responses and skills.

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